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TM 9-1718A

DEPARTMENT OF THE ARMY TECHNICAL MANUAL

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ORDNANCE MAINTENANCE

CONTINENTAL 12-CYLINDER ENGINE MODEL AV-1790-5A

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DEPARTMENT OF THE ARMY • MAY 1950

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TM 9–1718A
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TECHNICAL MANUAL

ORDNANCE MAINTENANCE

CONTINENTAL 12-CYLINDER ENGINE MODEL AV–1790–5A

CHANGES No. 1

DEPARTMENT OF THE ARMY
WASHINGTON 25, D. C., *24 August 1950*

TM 9–1718A, 19 May 1950, is changed as follows:

1. Paragraphs 117 through 142

Add the figure numbers before each of the reference numbers, as indicated below:

Figure No.	Ref. No.	Figure No.	Ref. No.
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2. Paragraph 143

Add the following figure and reference numbers before the items, as indicated below:

Figure No.	*Ref. No.*	
87, 91	172	Main bearing studs in crankcase.
87, 91	173	Main bearing cap nut.
87, 91	174	Crankcase cross bolts.
87, 88	175	Connecting rod bolts.
87, 114	176	Cylinder base nuts.
83, 92, 97	177	Damper hub screws (accessory end).
95, 96	178	Flywheel mounting screws.
	179	Spark plugs.
91, 95	180	Transmission adapter mounting nuts.
85, 114	181	Valve rocker support nuts.

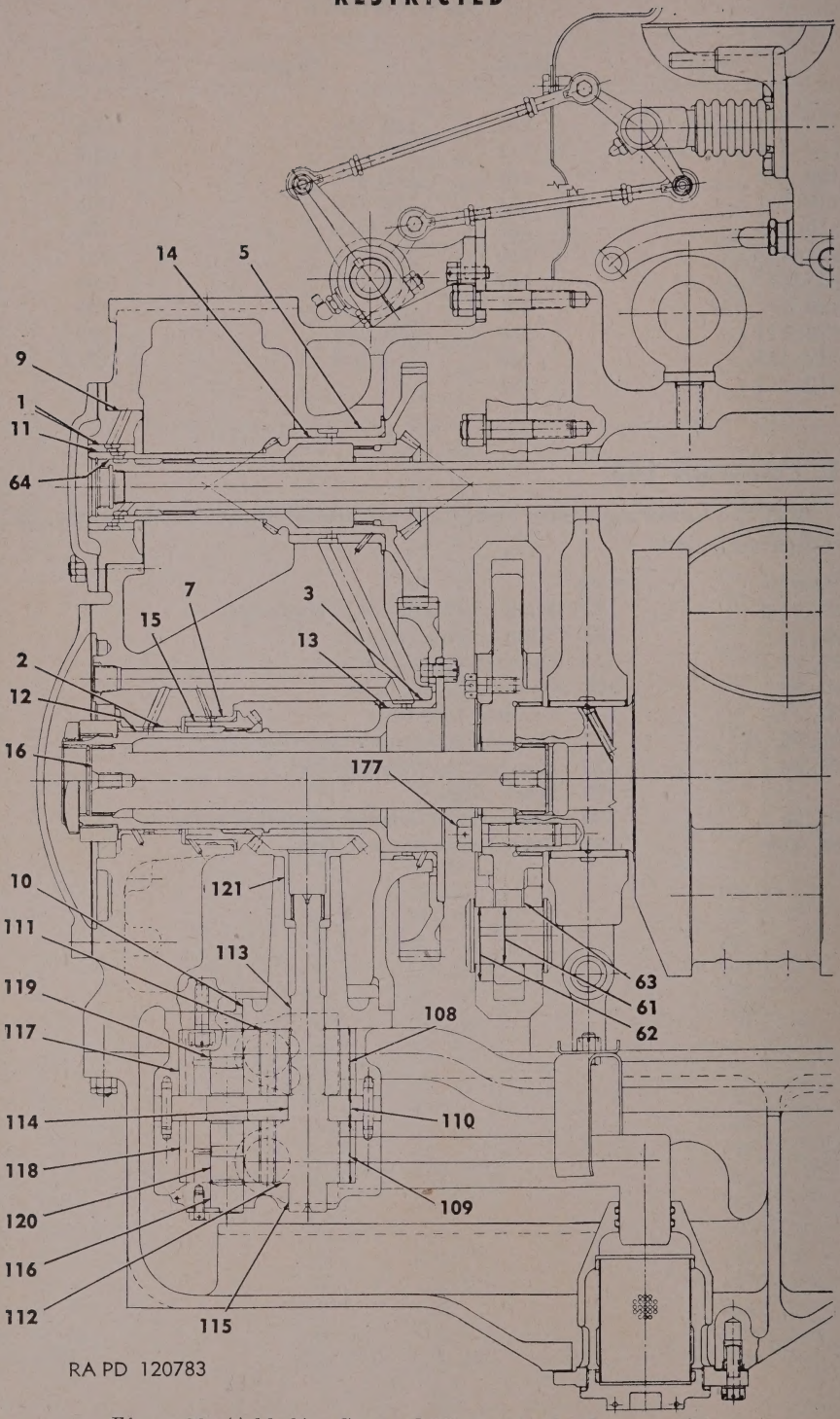

Figure 83. (Added.) *Serviceability standard reference points.*

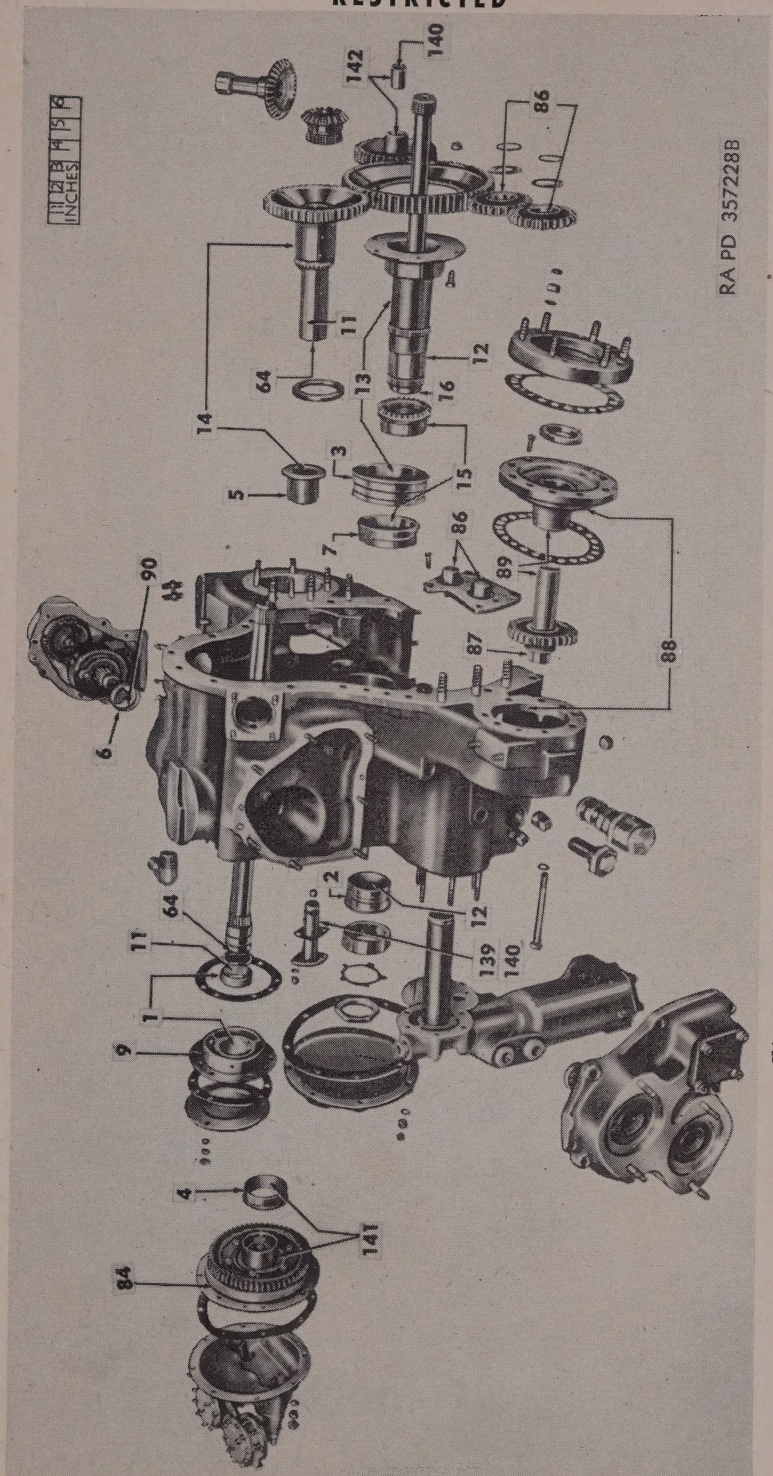

Figure 84. (Added.) *Serviceability standard reference points.*

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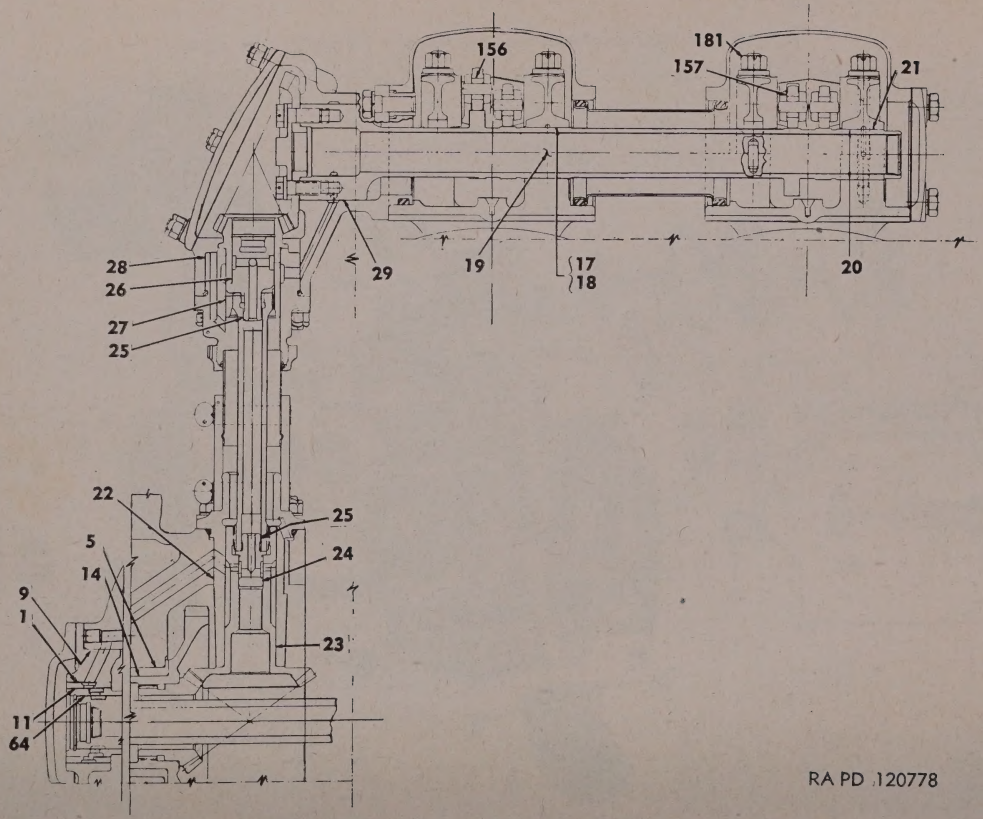

Figure 85. (Added.) *Serviceability standard reference points.*

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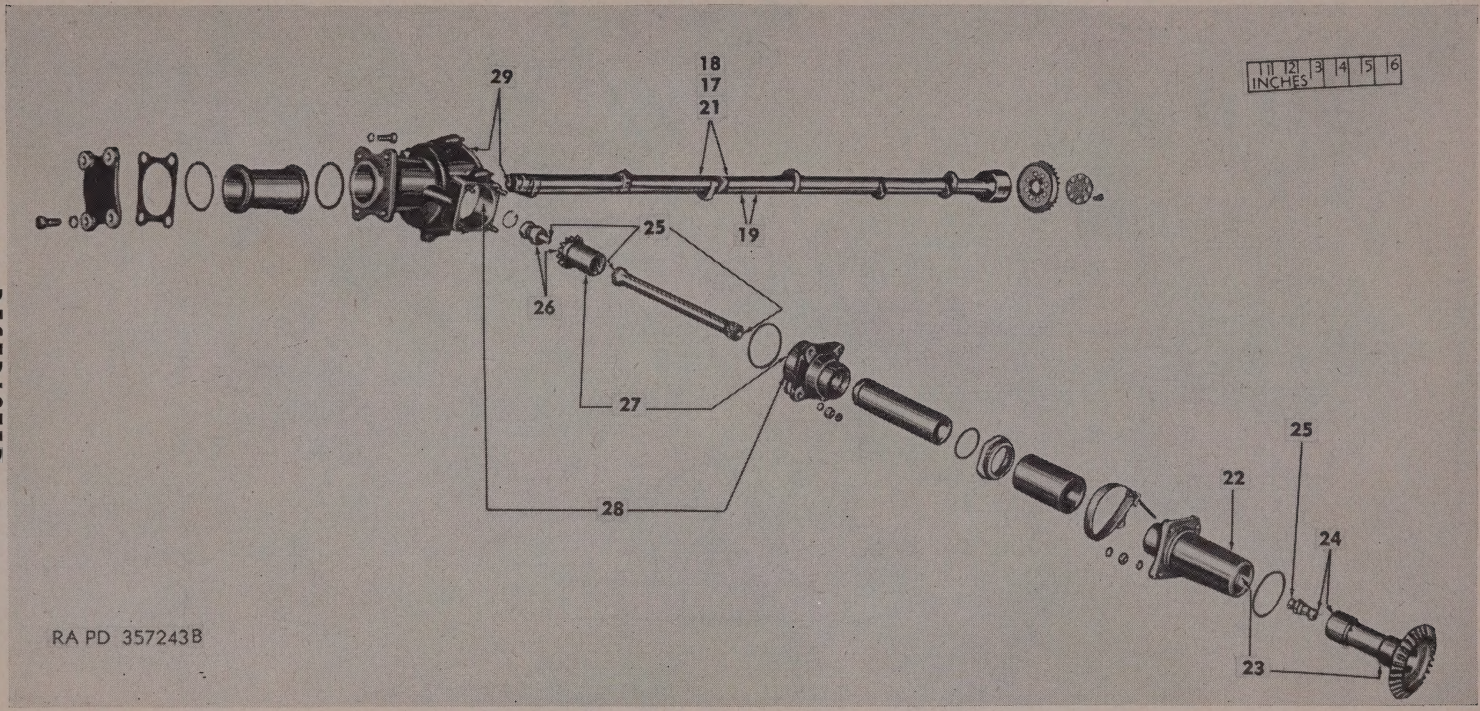

Figure 86. (Added.) *Serviceability standard reference points.*

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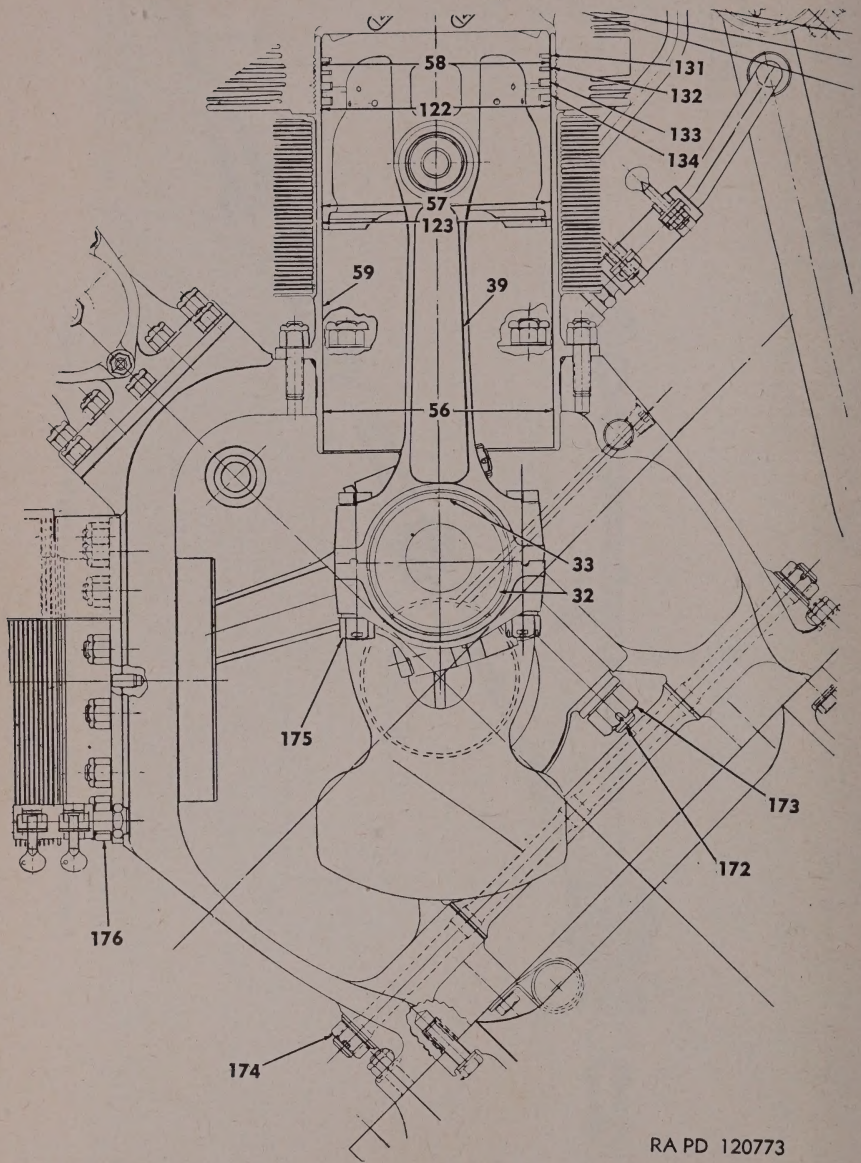

Figure 87. (Added.) *Serviceability standard reference points.*

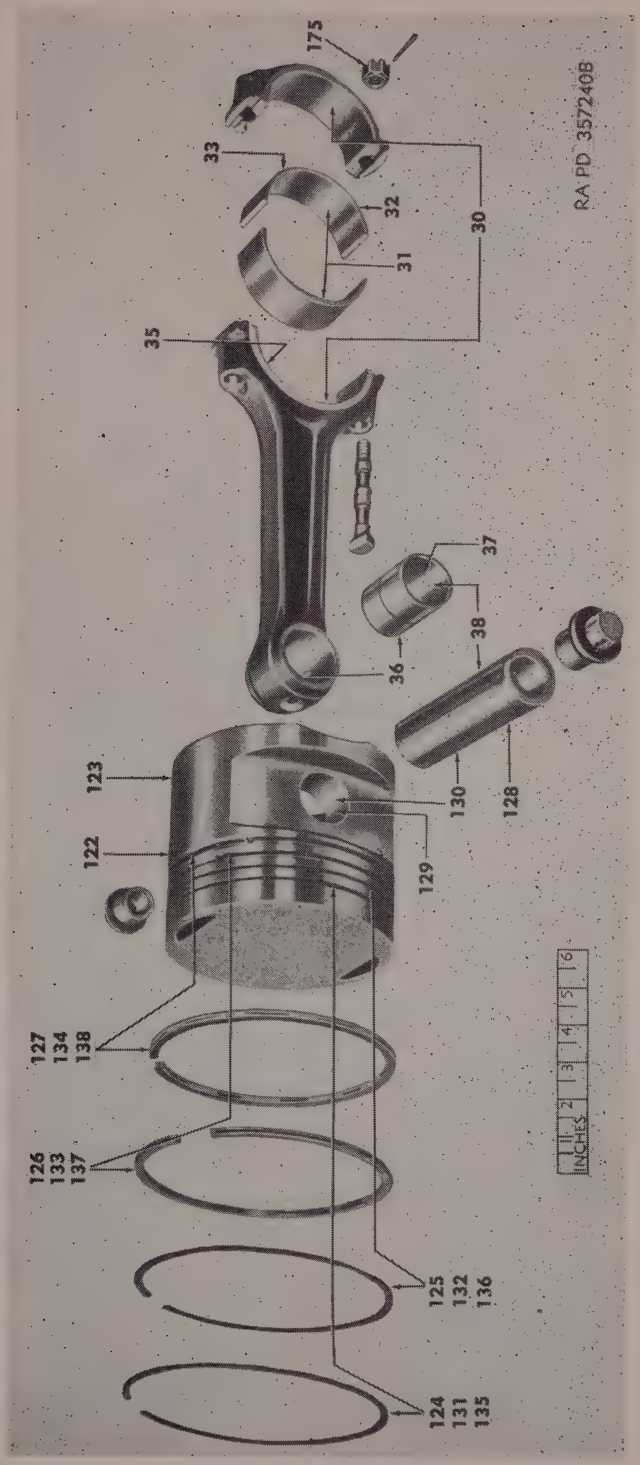

Figure 88. (Added.) *Serviceability standard reference points.*

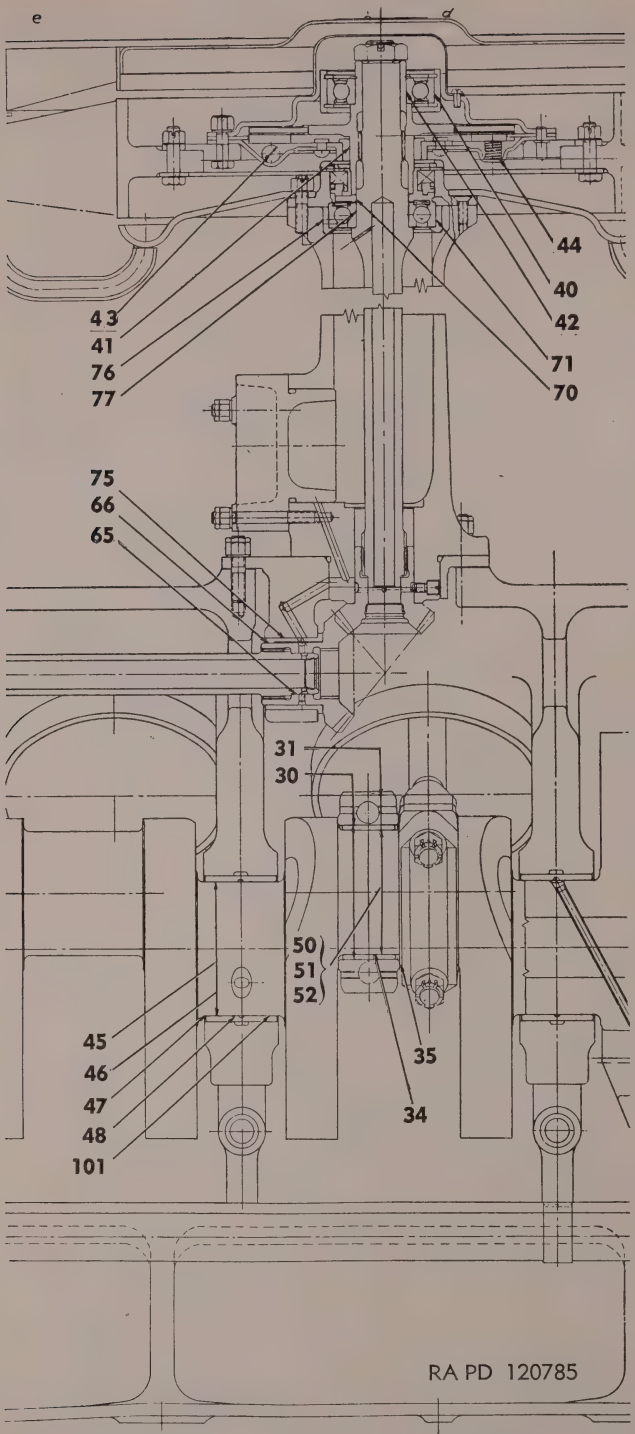

Figure 89. (Added.) *Serviceability standard reference points.*

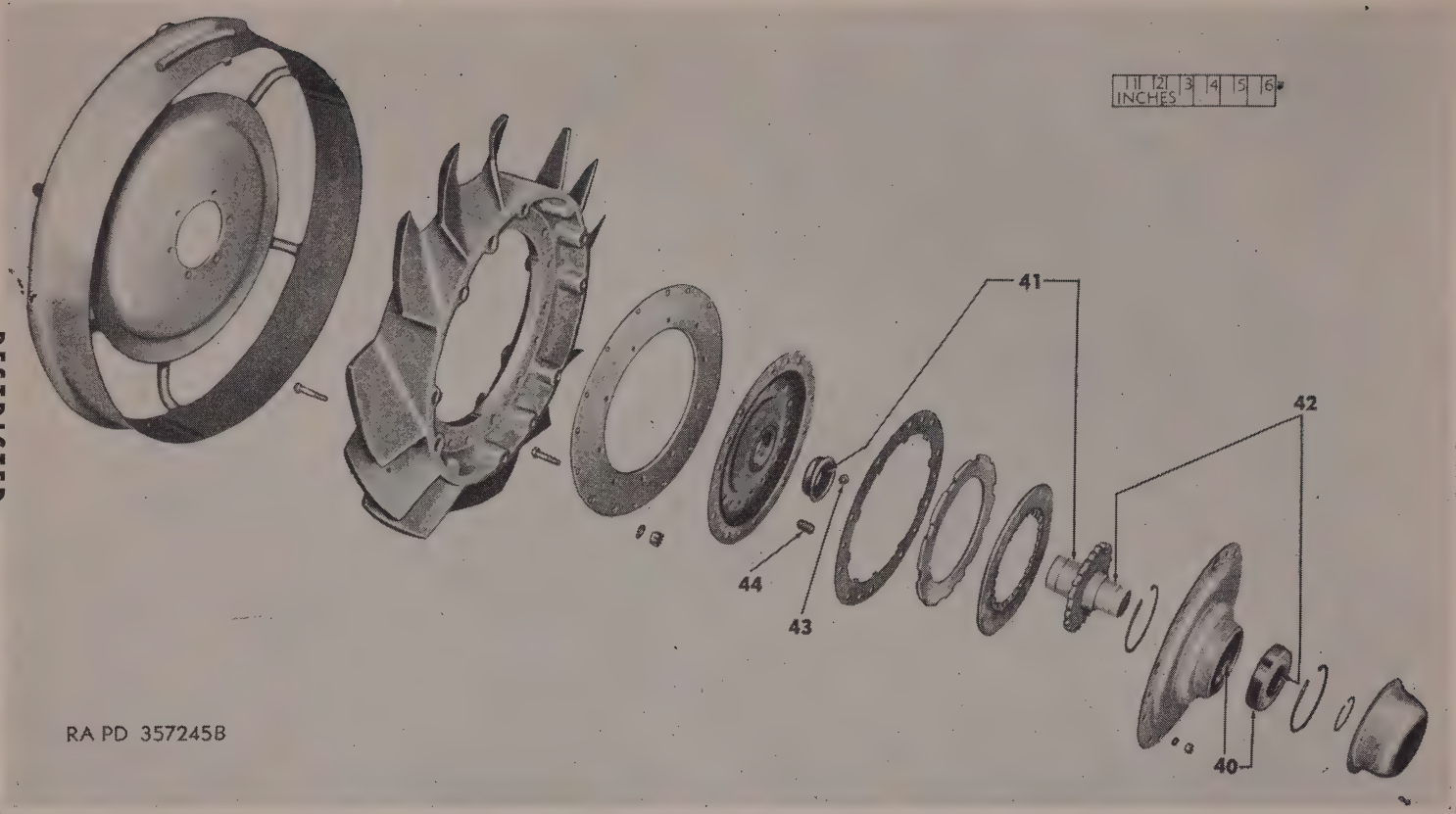

Figure 90. (Added.) *Serviceability standard reference points.*

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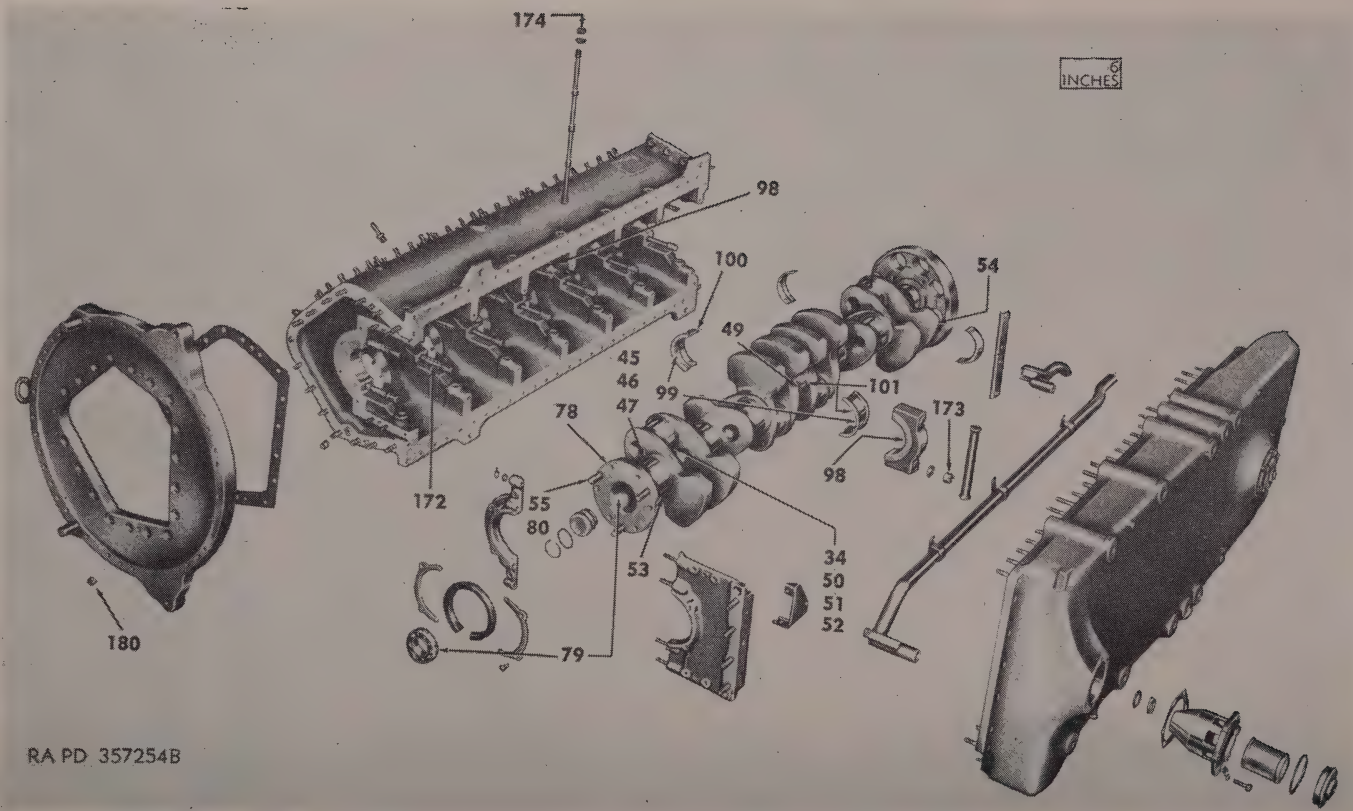


Figure 91. (Added.) *Serviceability standard reference points.*

Figure 92. (Added.) *Serviceability standard reference points.*

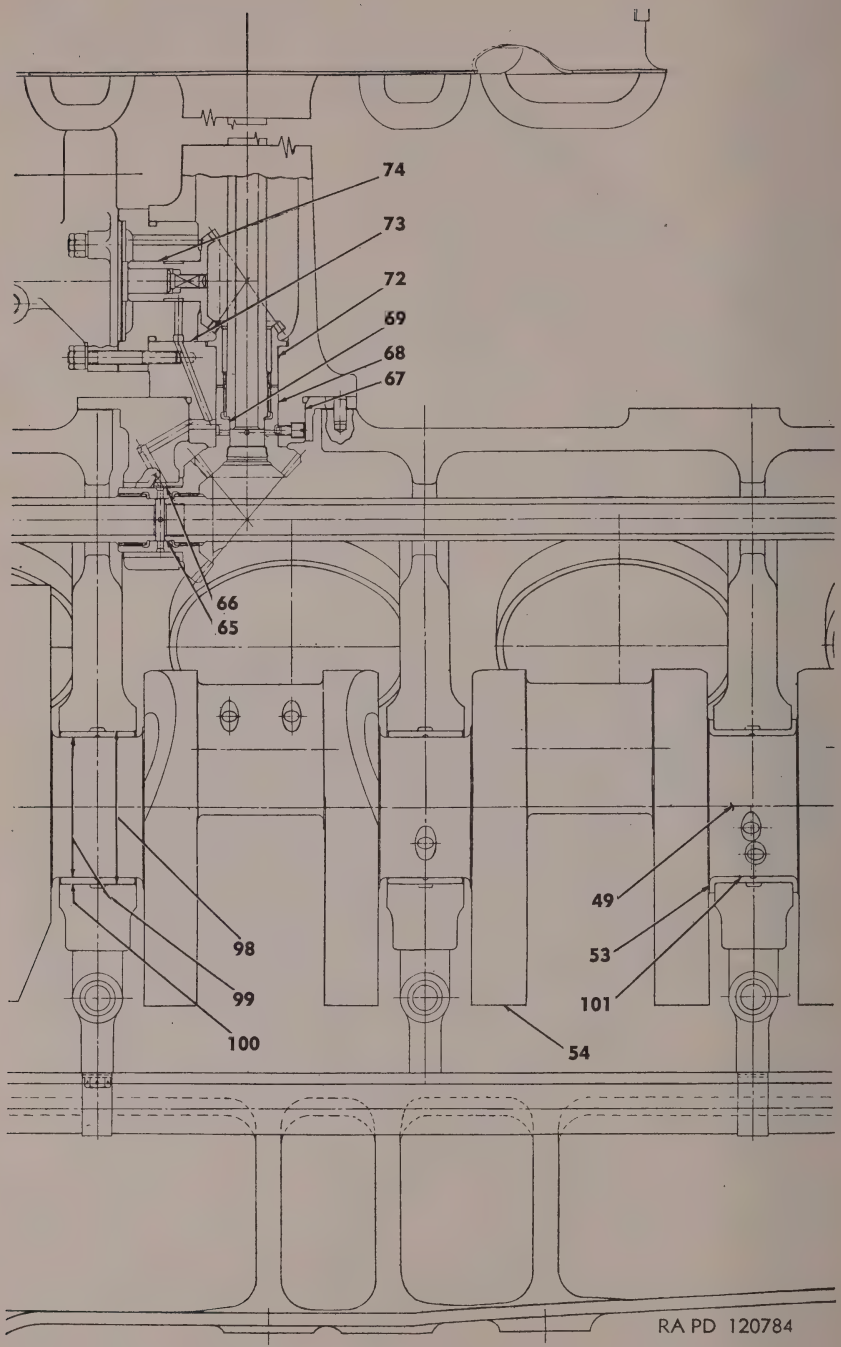


Figure 93. (Added.) *Serviceability standard reference points.*

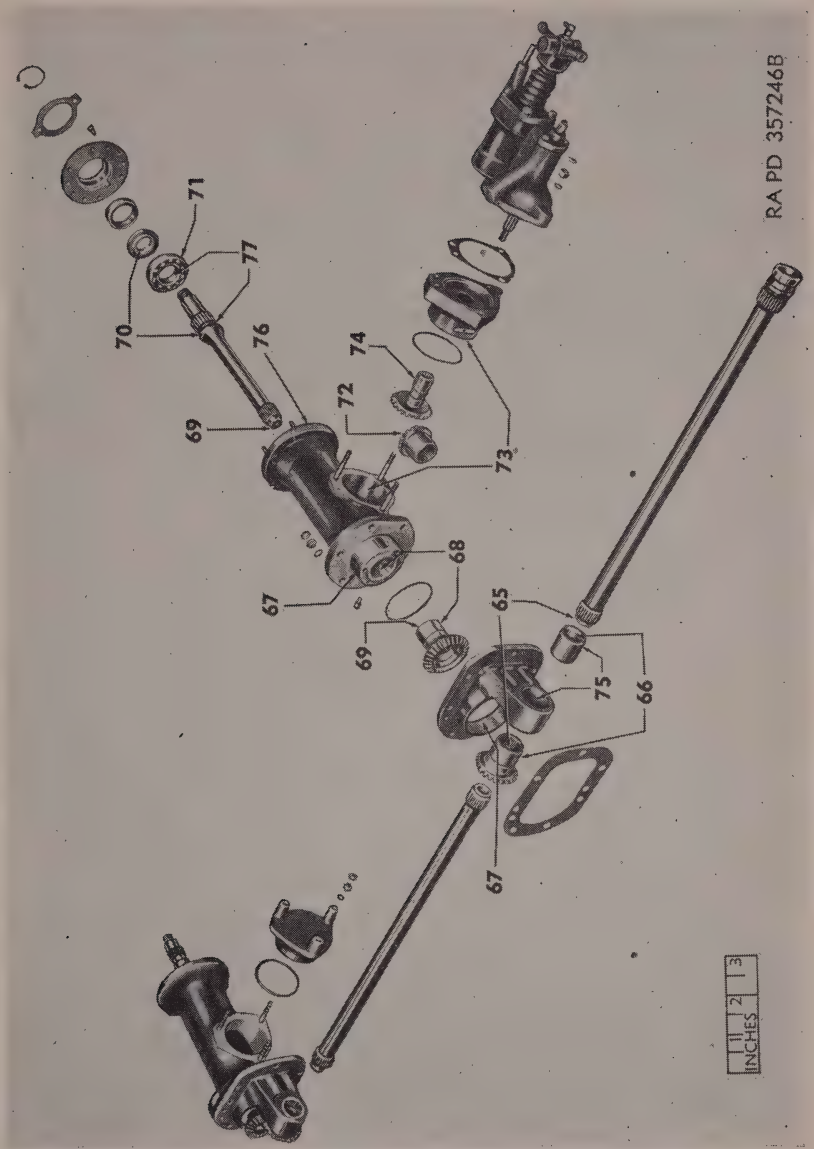
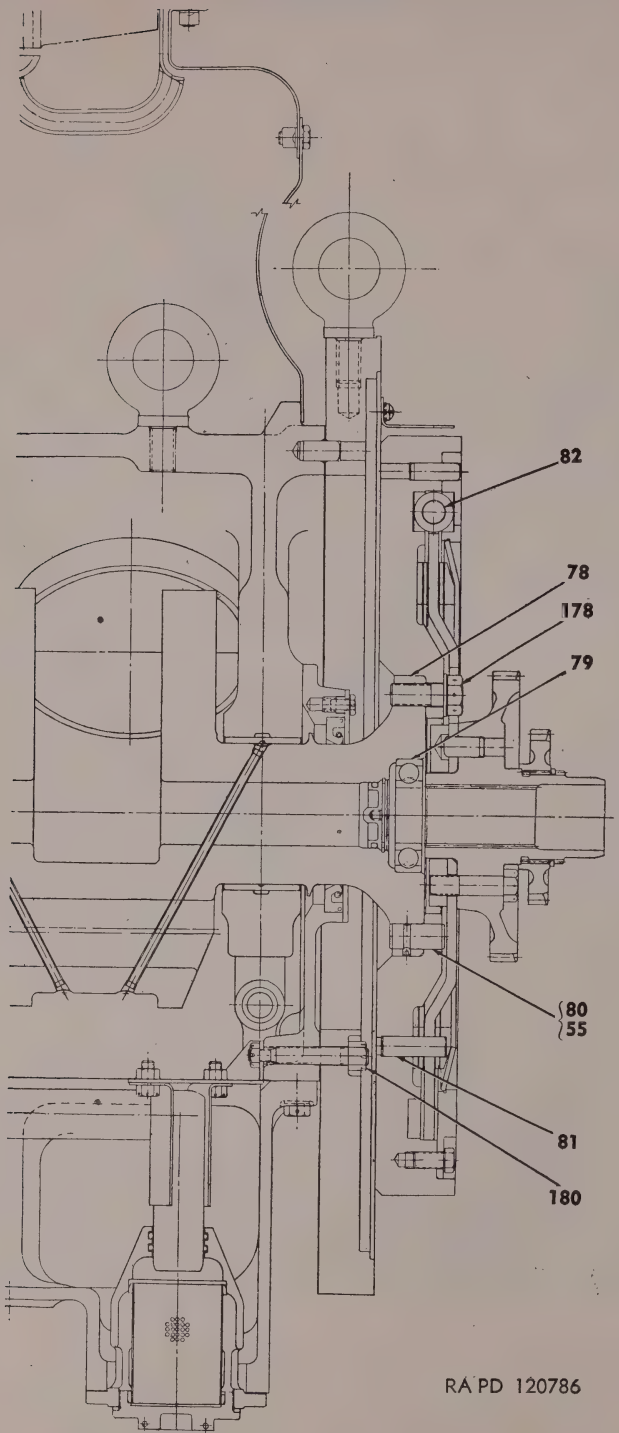


Figure 94. (Added.) *Serviceability standard reference points.*



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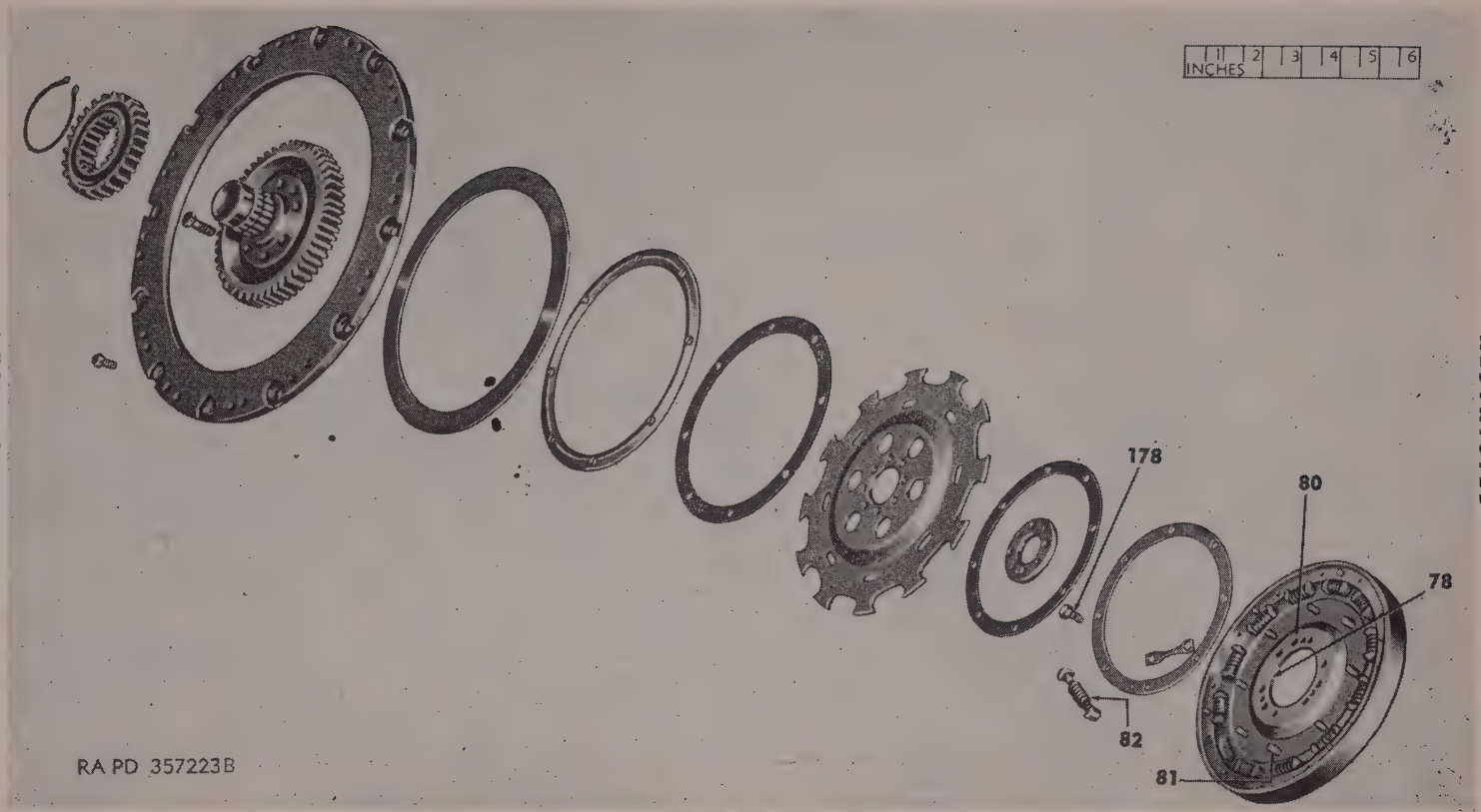

Figure 96. (Added.) *Serviceability standard reference points.*

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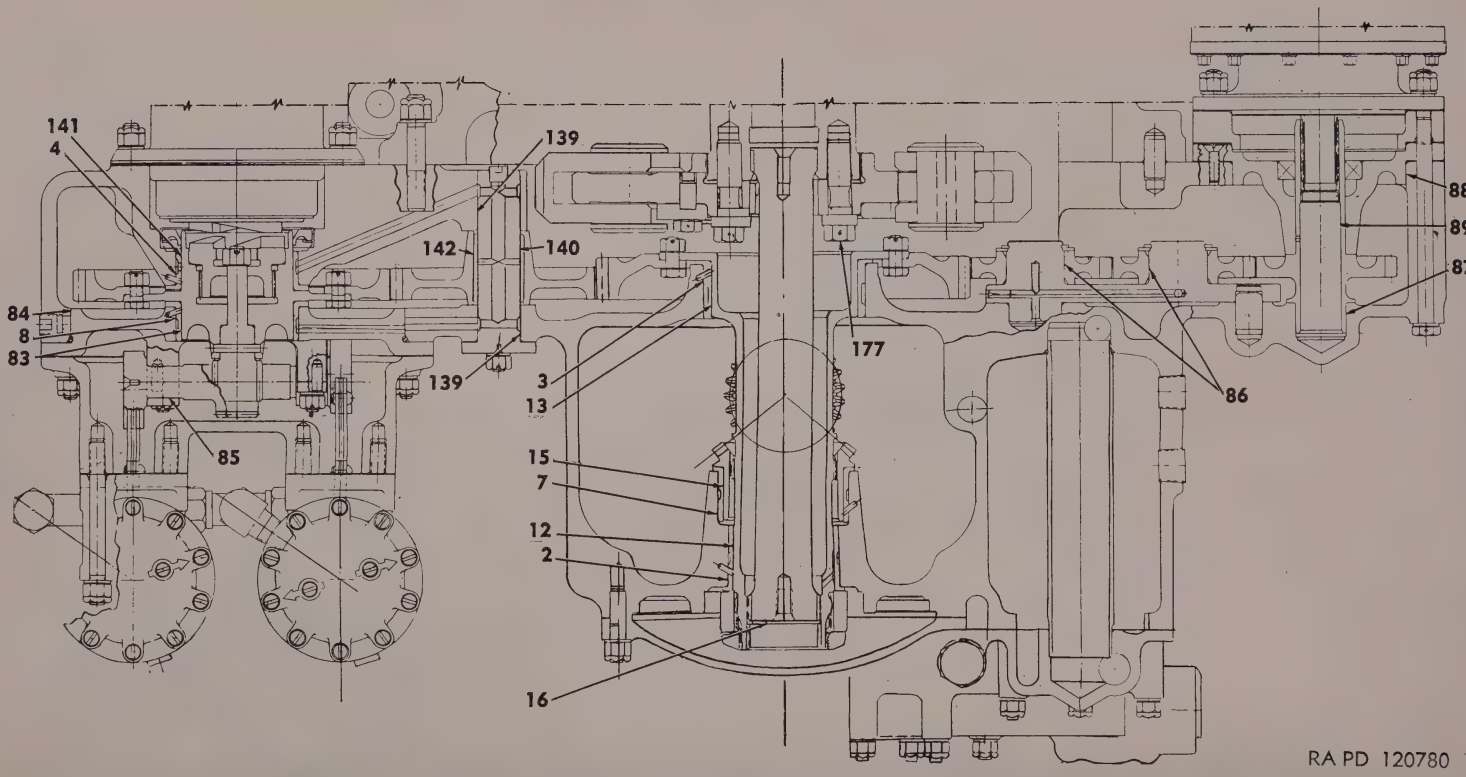

Figure 97. (Added.) *Serviceability standard reference points.*

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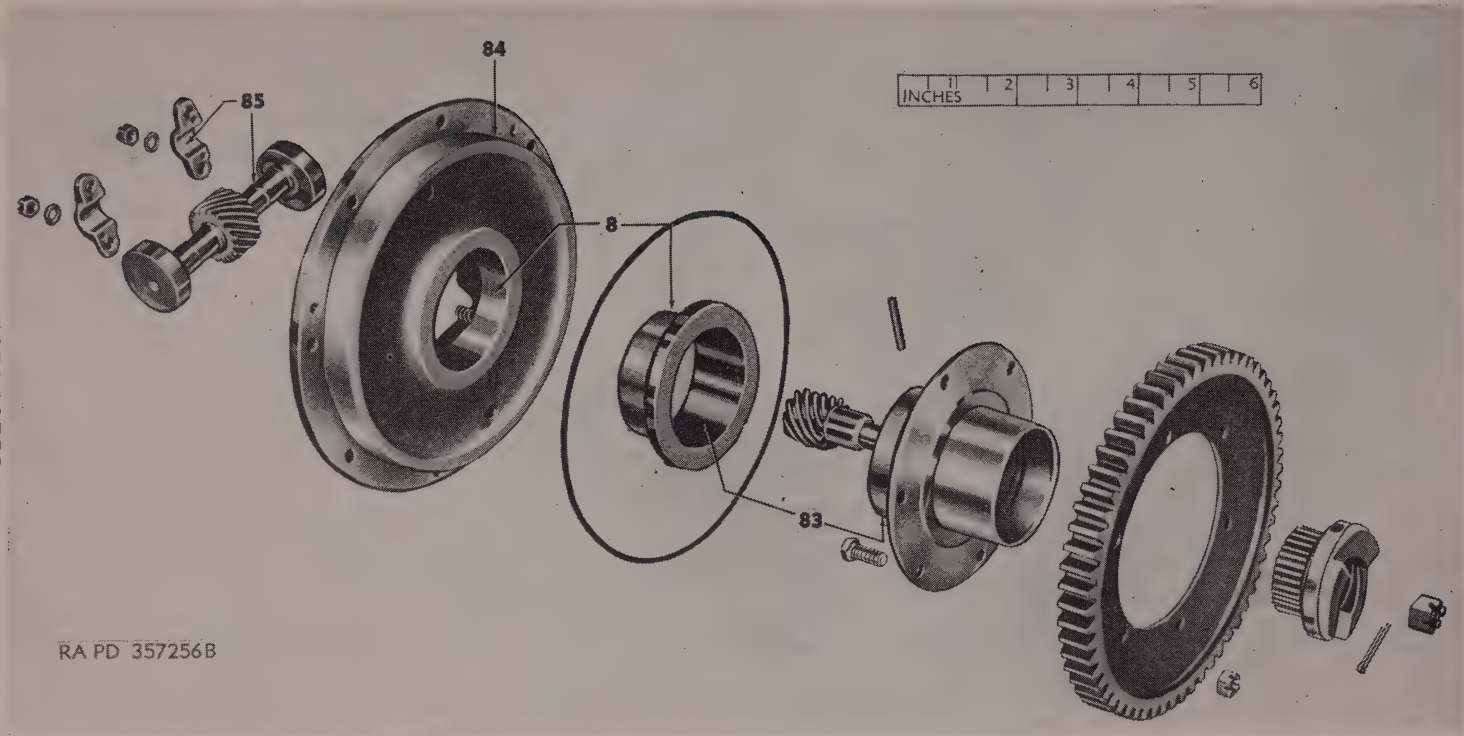

Figure 98. (Added.) *Serviceability standard reference points.*

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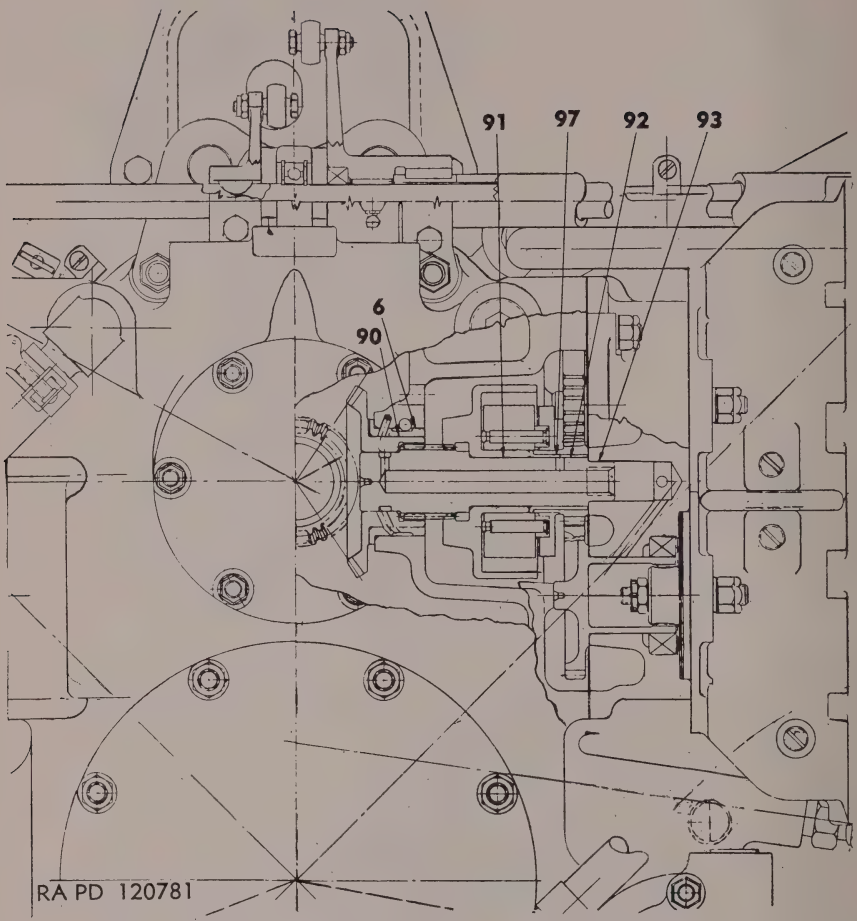

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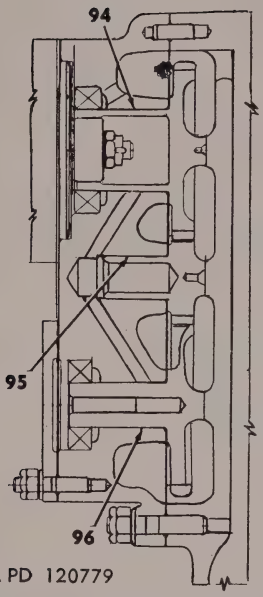

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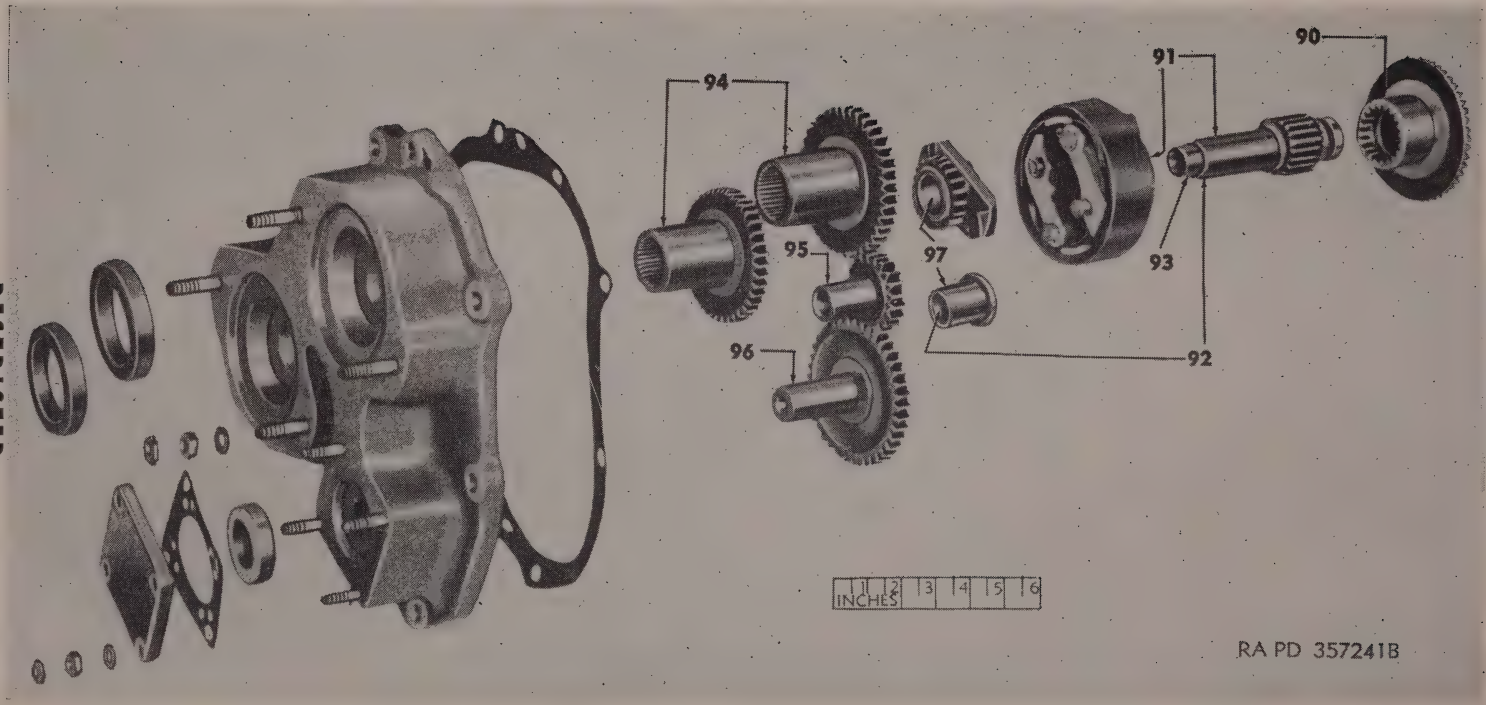

Figure 101. (Added.) *Serviceability standard reference points.*

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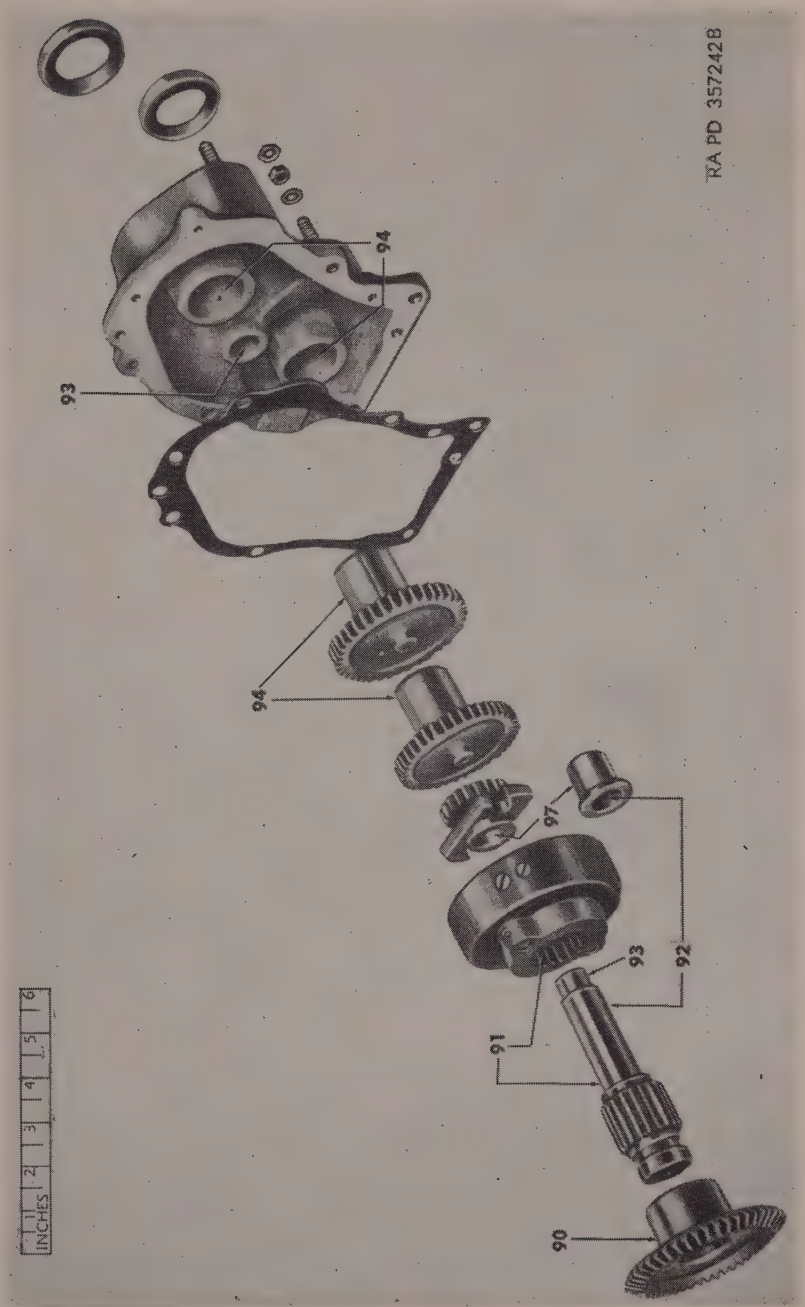

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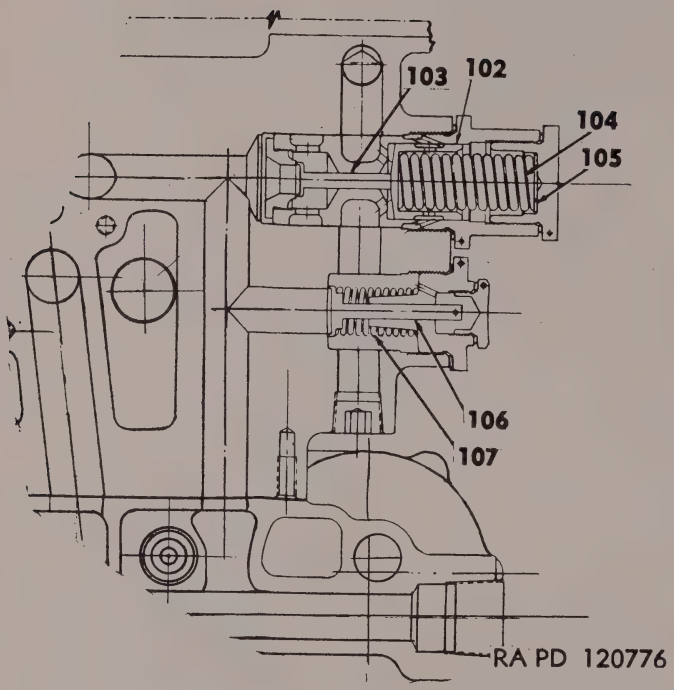

Figure 103. (Added.) *Serviceability standard reference points.*

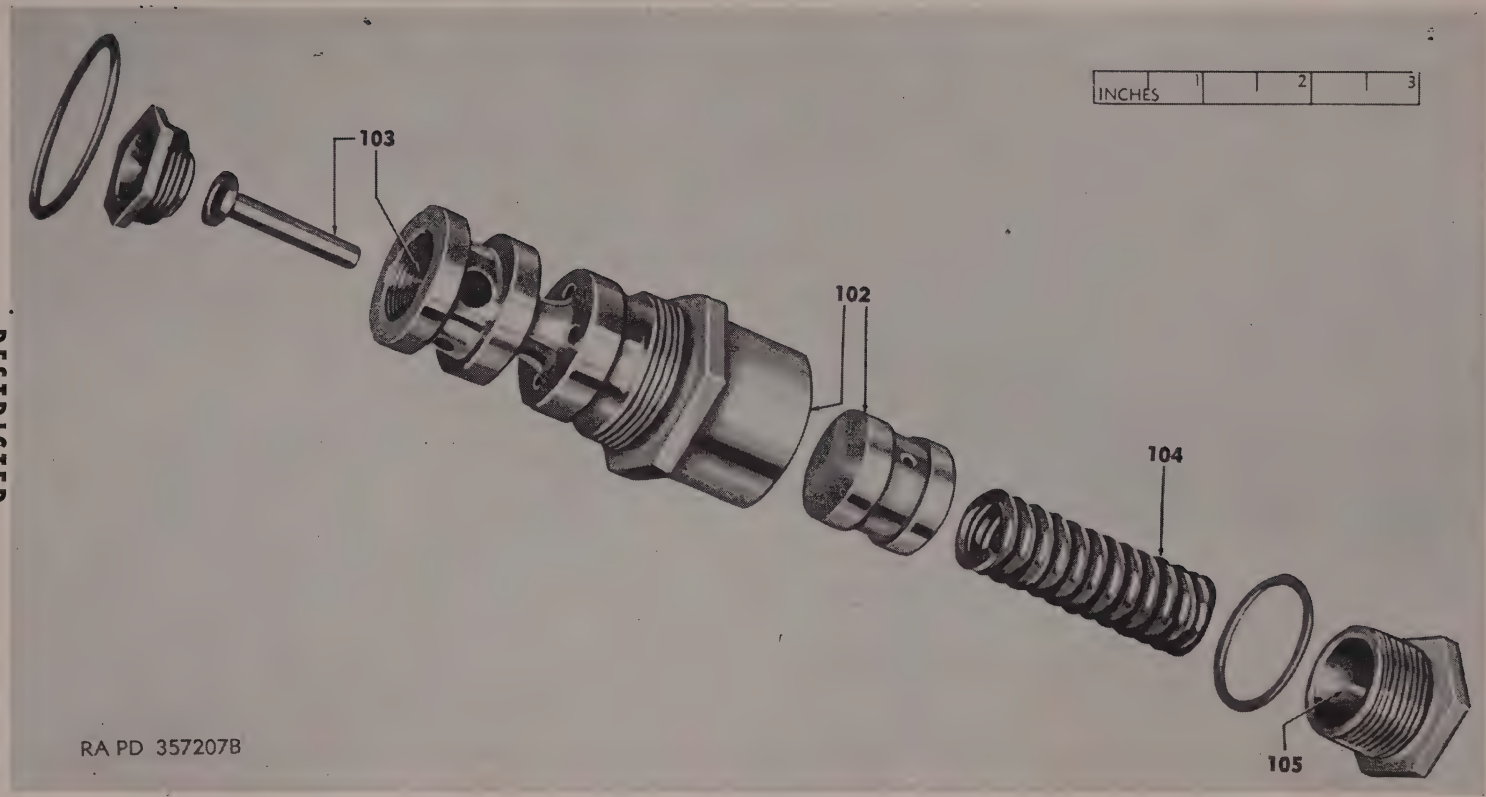

Figure 104. (Added.) *Serviceability standard reference points.*

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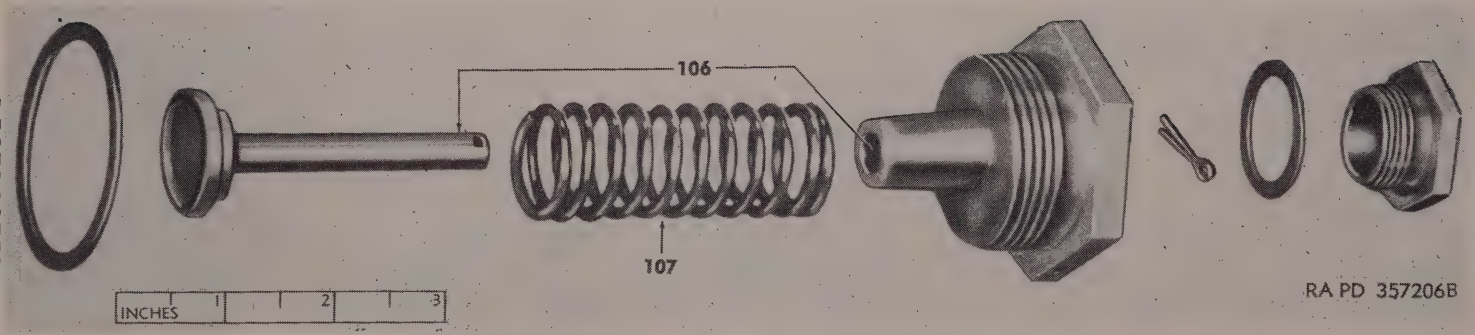

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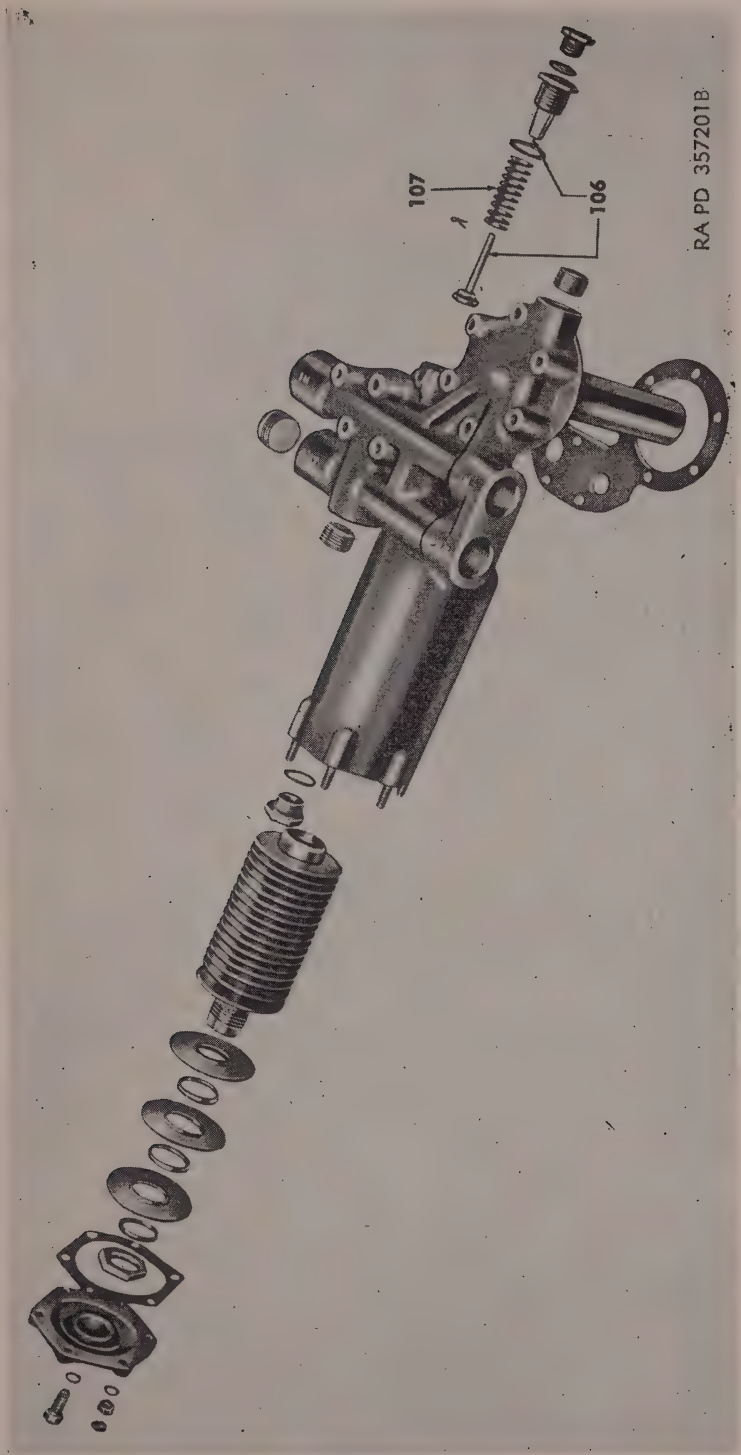

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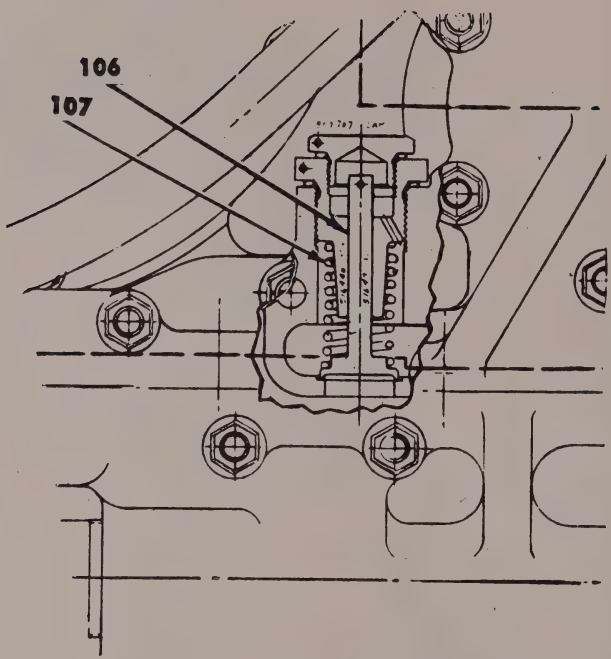

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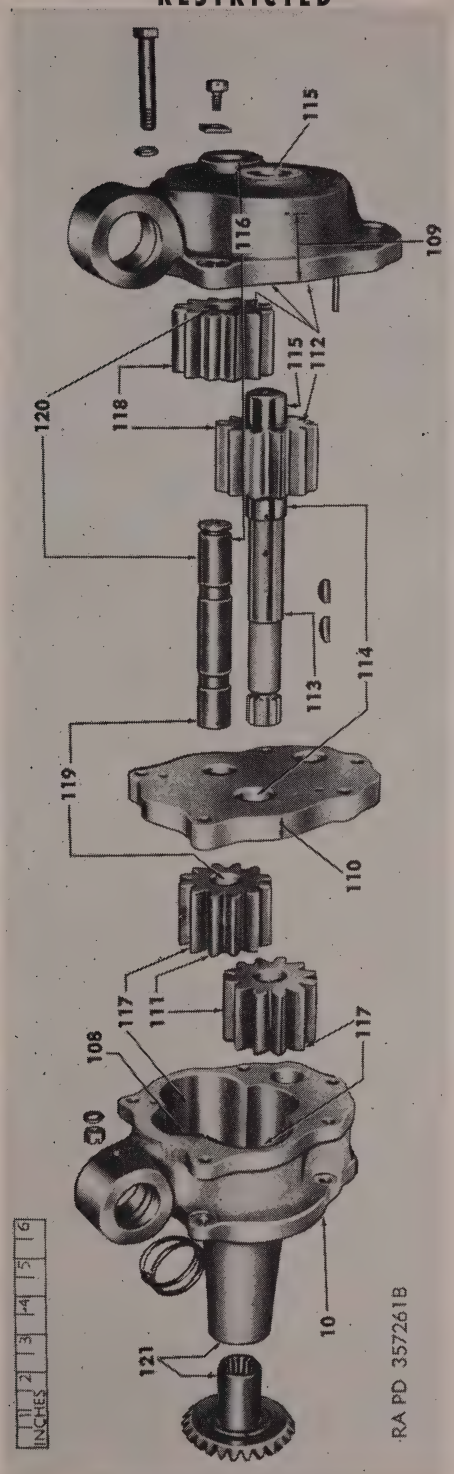
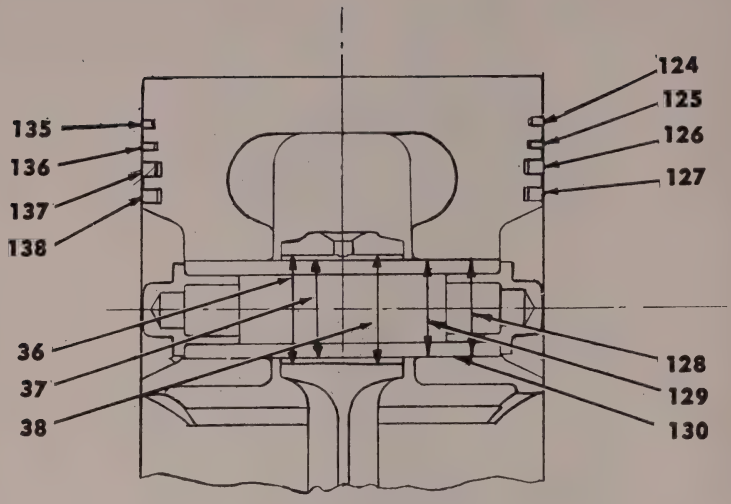


Figure 108. (Added.) *Serviceability standard reference points.*



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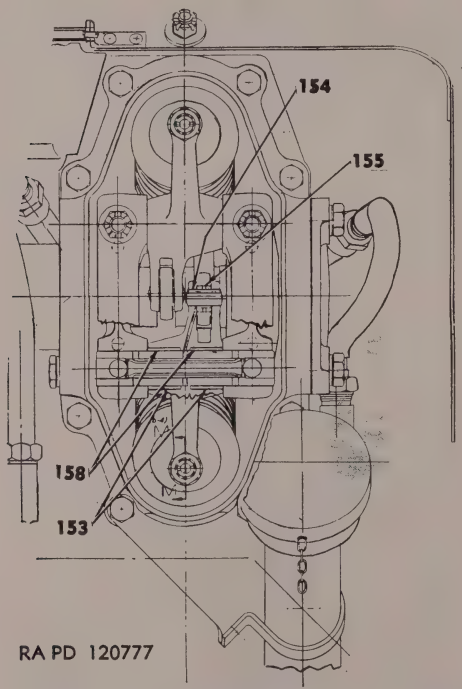
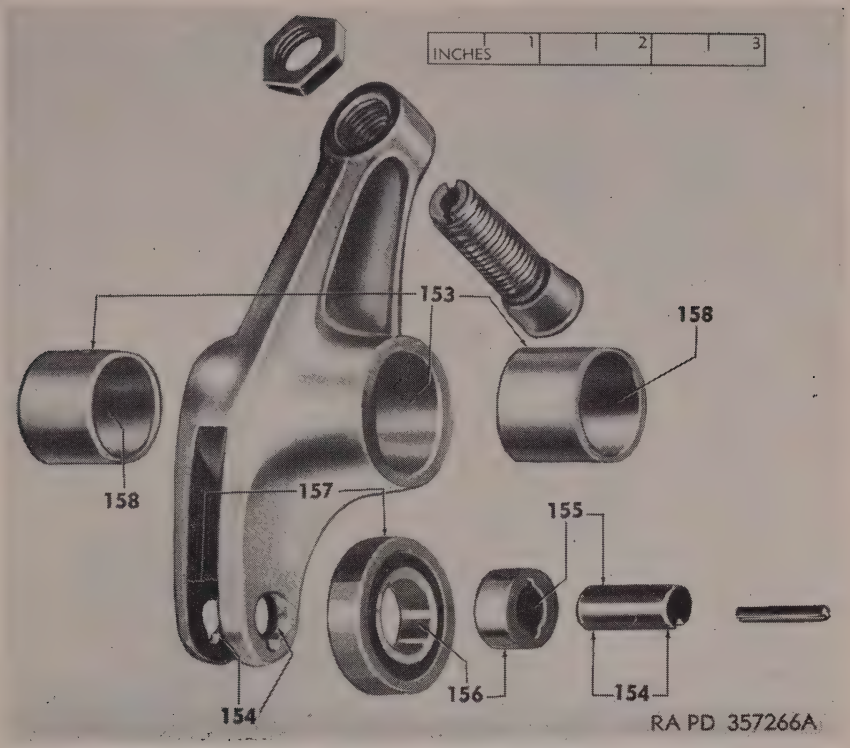


Figure 110. (Added.) *Serviceability standard reference points.*



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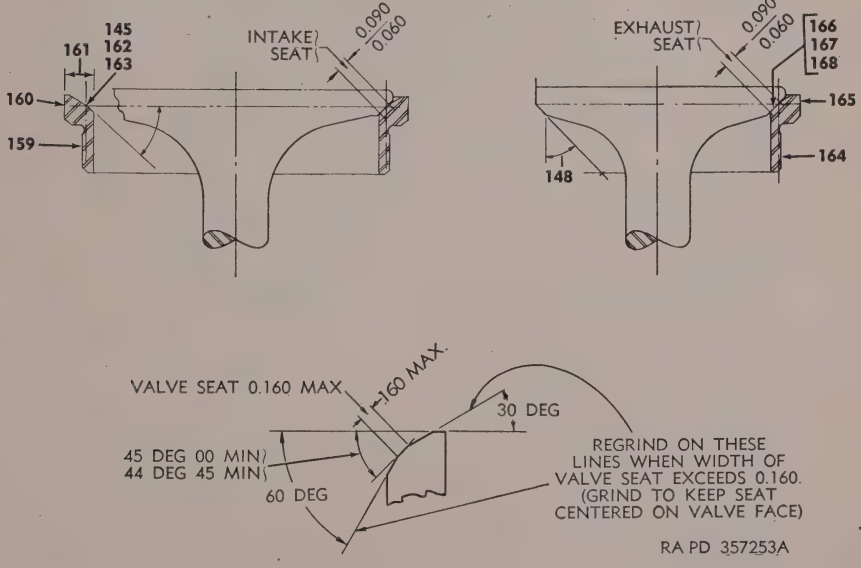

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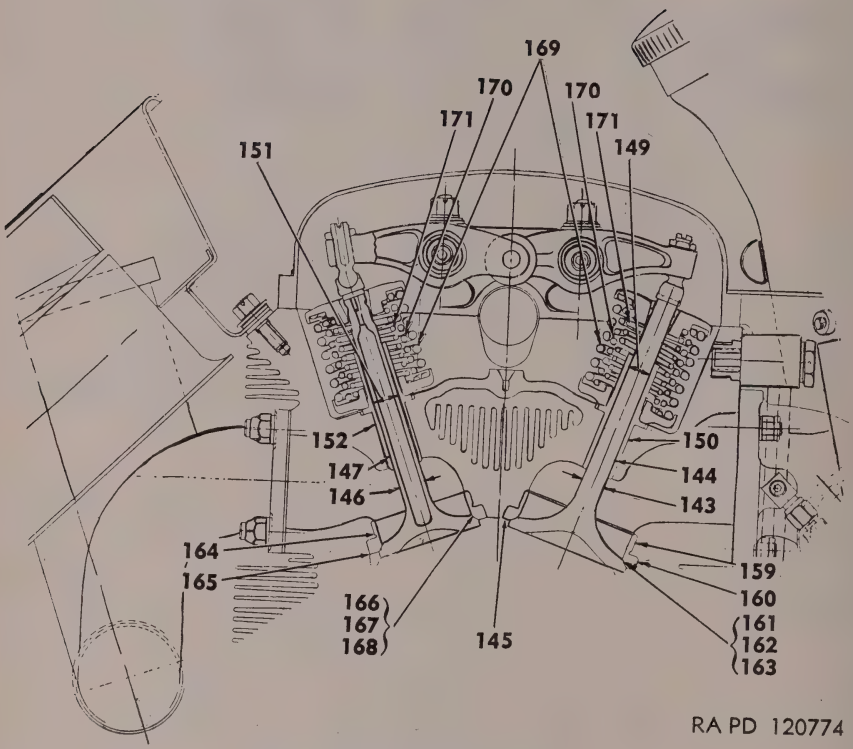

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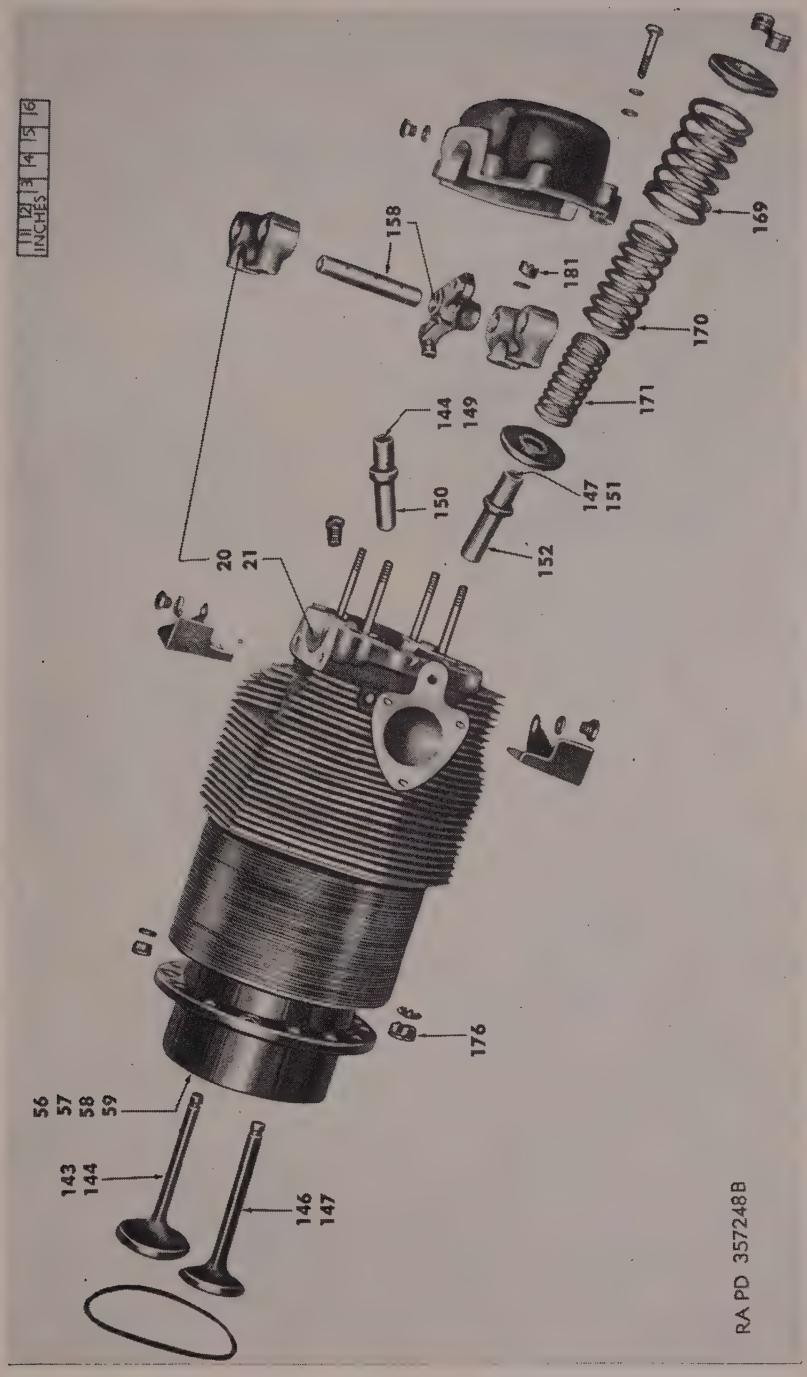

Figure 114. (Added.) *Serviceability standard reference points.*

[AG 300.7 (18 Aug 50)]

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Major General, USA
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TM 9-1718A

ORDNANCE MAINTENANCE

CONTINENTAL 12-CYLINDER ENGINE MODEL AV-1790-5A

DEPARTMENT OF THE ARMY • *MAY 1950*

United States Government Printing Office
Washington : 1950

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DEPARTMENT OF THE ARMY

WASHINGTON 25, D. C., *19 May 1950*

TM 9–1718A is published for the information and guidance of all concerned.

This manual is correct to 6 April 1950. This first edition is being published in advance of complete technical review of all concerned. Any errors or omissions will be brought to the attention of Chief of Ordnance, Washington 25, D. C., Attention: ORDFM—Pub.

[AG 412.5 (2 May 50)]

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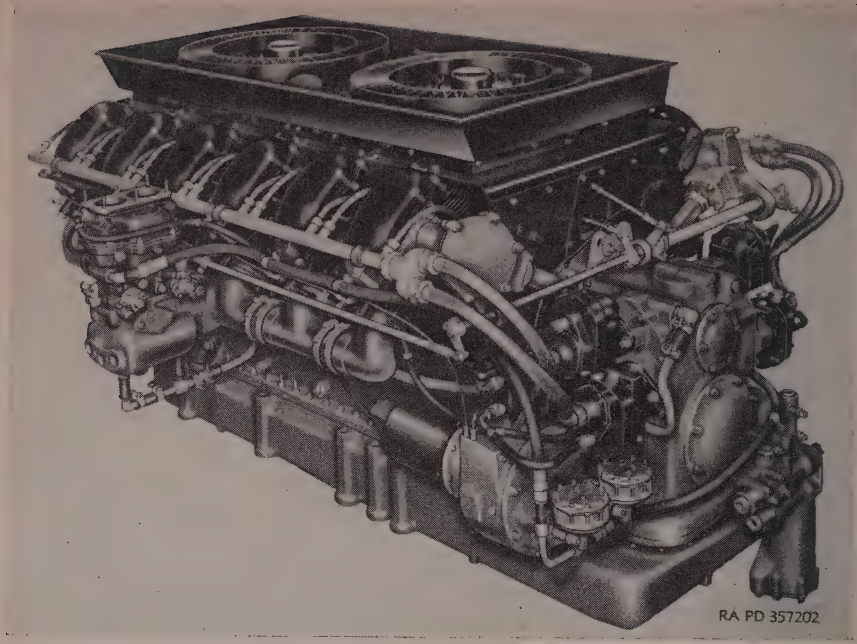

Figure 1. Left front of engine.

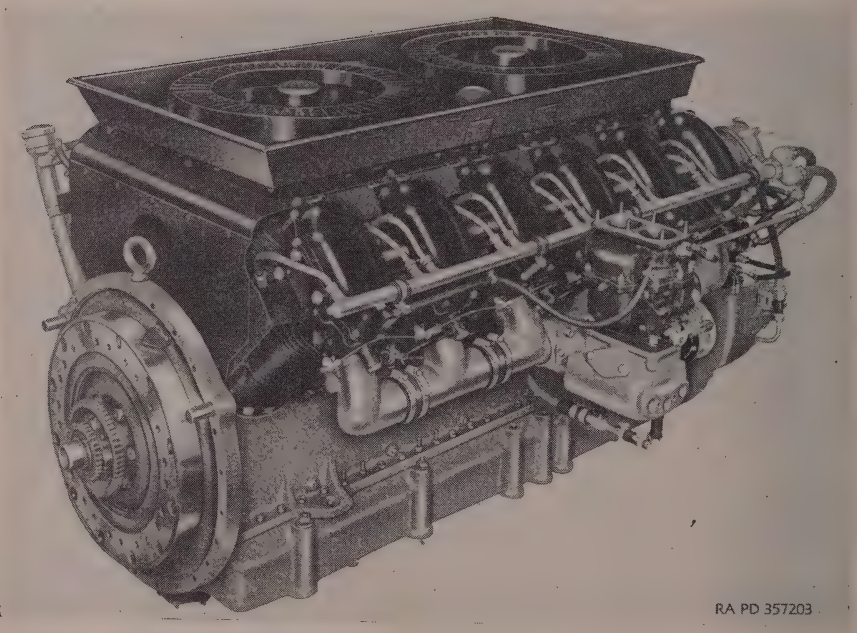

Figure 2. Left rear of engine.

CHAPTER 1

INTRODUCTION

Section I. GENERAL

1. Scope

a. These instructions are published for the information and guidance of personnel responsible for field and depot maintenance procedures for the Continental 12-cylinder engine, model AV–1790–5A. Instructions contained in this manual are based on the engine as installed in the Medium Tank M46. They contain information on maintenance which is beyond the scope of the tools, equipment, or supplies normally available to using organizations. This manual does not contain information which is intended primarily for the using organization, since such information is available to ordnance maintenance personnel in the pertinent operator's technical manuals or field manuals.

b. This manual contains a description of, and procedure for removal, disassembly, inspection, repair, rebuild, and assembly of the stripped engine. This manual does not include maintenance information on the accessories indicated in *d* through *g* below. The appendix contains a list of current references, including supply catalogs, technical manuals, and other available publications applicable to the matériel.

c. TM 9–718, and any other operator's manual covering matériel in which this engine is installed, contains operating and lubricating instructions for the matériel and contains all maintenance operations allocated to using organizations in performing maintenance work within their scope.

d. TM 9–1826B contains service information on the carburetor.

e. TM 9–1828A contains service information on the fuel pump and fuel filter.

f. TM 9–1825C contains service information on the generator and starter.

g. TM 9–1825E contains service information on the magneto.

2. Field and Depot Maintenance Allocation

The publication of instructions for complete disassembly and rebuild is not to be construed as authority for the performance by field maintenance units of those functions which are restricted to depots and arsenals. In general, the prescribed maintenance responsibilities will apply as deflected in the allocation of tools and maintenance parts

listed in the appropriate columns of the current ORD 8 supply catalogs pertaining to vehicles using this engine. Instructions for depot maintenance are to be used by maintenance companies in the field only when the tactical situation makes the repair functions imperative. Provisions of parts listed in the depot stock guide column of ORD 8 supply catalogs will be made to field maintenance units only when the emergency nature of the maintenance to be performed has been certified by a responsible officer of the requisitioning organization.

3. Forms, Records, and Reports

a. General. Forms, records, and reports are designed to serve necessary and useful purposes. Responsibility for the proper execution of these forms rests upon commanding officers of all units maintaining this equipment. It is emphasized, however, that forms, records, and reports are merely aids. They are not a substitute for thorough practical work, physical inspection, and active supervision.

b. Authorized forms. The forms, records, and reports generally applicable to units maintaining this equipment are listed below. No forms other than approved Department of the Army forms will be used. For a current and complete listing of all forms, see SR 310–20–6.

WD AGO Form 9–71	Locator and Inventory Control Card.
WD AGO Form 9–72	Ordnance Stock Record Card.
WD AGO Form 9–76	Request for Work Order.
WD AGO Form 9–77	Job Order Register.
WD AGO Form 9–78	Job Order.
WD AGO Form 9–79	Parts Requisition
WD AGO Form 9–80	Job Order File.
WD AGO Form 9–81	Exchange Part or Unit Identification Tag.
DA AGO Form 461–5	Limited Technical Inspection.
DA AGO Form 468	Unsatisfactory Equipment Report.
WD AGO Form 865	Work Order.
WD AGO Form 866	Consolidation of Parts.
WD AGO Form 867	Status of Modification Work Order.

Section II. DESCRIPTION AND DATA

4. Description

a. The Continental Model AV–1790–5A engine is a 12-cylinder, V-type, 4-cycle, air-cooled engine. The cylinders are individual replaceable units, have the valve rocker arm assemblies in the head, and are arranged in two banks of six each, with a camshaft for each bank. Two mechanically driven fans located on top of the engine are provided to circulate air around the cylinders for cooling. Baffles are

mounted on the cylinders to direct air flow. An accessory case on the front of the engine provides a means for mounting and driving the engine accessories.

b. Two conventional, double-venturi, downdraft carburetors are furnished, one for each bank of six cylinders. Fuel is supplied to the carburetors by two fuel pumps mounted on the lower left side of the accessory case. The fuel pumps are interconnected to maintain a balanced pressure to each carburetor.

c. Dual ignition is provided by four individual magnetos mounted on the accessory case, two magnetos for each bank of six cylinders. Each magneto fires six spark plugs. The two upper magnetos fire spark plugs nearest the accessory end of each cylinder while the lower two magnetos fire the spark plugs at the flywheel end of each cylinder. An ignition harness is provided to connect the two magnetos to the 12 spark plugs on each side of the engine. The ignition harness and magnetos are shielded to prevent radio interference.

d. A forced-feed lubrication system is used to lubricate the engine parts. Oil under pressure is supplied by a combination scavenge and pressure pump mounted on the lower side of the accessory case. The scavenge pump transfers oil from the large compartment of the oil pan to the small compartment for the pressure pump supply. In normal

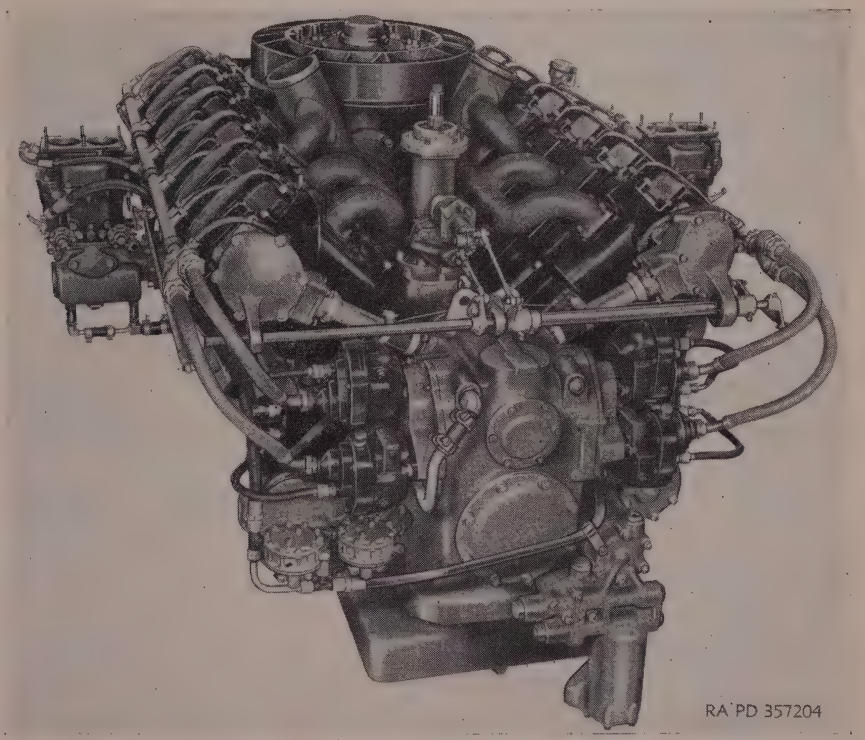

Figure 3. Front view of engine—shrouds and front fan removed.

operation, the oil passes from the pressure pump through external oil coolers, and returns to the engine through an oil filter. The oil flow is controlled by three valves, oil cooler bypass valve, oil pressure control valve, and a filter bypass valve.

e. A generator is mounted on the right side and a starter on the left side of the rear of the accessory case.

5. Engine Nomenclature

In this publication, the following terms will be used to identify the location of parts and assemblies:

a. The accessory end of the engine will be called the "front."

b. The flywheel end of the engine will be called the "rear."

c. As viewed from the accessory end, the side to the right will be called the "right side" or "right bank," and the side to the left will be called the "left side."

d. Cylinders and valve rockers, pistons, and connecting rods and bearings are numbered from 1 to 6 for each side starting from the accessory end. They are identified further by the letter "R" or "L" following the position number. The intake and exhaust valve rockers are identified further by the letters "INT" or "EX."

6. Tabulated Data

Make and type	Continental, 12-cylinder, air-cooled, V-type engine.
Model	AV–1790–5A.
Over-all dimensions (including flywheel assembly)	
Length	73.69 in.
Width	61.00 in.
Height	40.88 in.
Dry weight complete with flywheel and transmission adapter	2,505 lb.
Horsepower (gross)	810 at 2,800 rpm.
Torque (gross)	1,560 ft.-lb. at 2,400 rpm.
Number of cylinders	12.
Cylinder arrangement	Individual cylinders in a 90° upright vee.
Cylinder cooling	Air supplied by 2 integral fans.
Drive from crankshaft	Direct.
Crankshaft rotation	Counterclockwise viewed from the flywheel end.
Induction system	Natural aspiration.
Numbering of cylinders from accessory to flywheel end	
Right bank (as viewed from accessory end)	1–2–3–4–5–6.
Left bank (as viewed from accessory end)	1–2–3–4–5–6.
Oil capacity	16 gal.

CHAPTER 2

PARTS, SPECIAL TOOLS, AND EQUIPMENT FOR FIELD AND DEPOT MAINTENANCE

7. Parts, Tools, and Equipment

a. General. Tools and equipment and additional spare parts over and above those available to the using organization are supplied to ordnance field maintenance units and depots for maintaining, repairing, and/or rebuilding the matériel.

b. Parts. Parts are listed in Department of the Army Supply Catalog ORD 8 SNL G–244 and in any other ORD 8 catalog covering a major item incorporating this matériel, which are the authority for requisitioning replacements. Parts not listed in an ORD 8 catalog, but required by depot shops in rebuild operations, may be requisitioned from the listing in the corresponding ORD 9 catalog.

c. Common Tools and Equipment. Standard and commonly used tools and equipment having general application to this matériel are listed in Department of the Army Supply Catalog ORD 6 SNL G–27, Section 2, which is the authority for requisitioning replacements. They are not identified specifically in this manual.

8. Special Tools and Equipment

The special tools and equipment tabulated in table I are listed in Department of the Army Supply Catalog ORD 6 SNL G–27, Section 1. The tabulation contains only those special tools and equipment necessary to perform the operations described in this manual, is included for information only, and is not to be used as a basis for requisitions.

Table I. Special Tools and Equipment for Field and Depot Maintenance

Item	Identifying number	References		Use
		Fig.	Par.	
BUSHING, pilot	41–B–2181–150	4	55	Pilot for exhaust valve reamers.
BUSHING, pilot	41–B–2181–175	4	55	Pilot for intake valve reamers.
COMPRESSOR, valve spring	41–C–2558–900	4, 46	54, 56	Removing and replacing valve springs.
DRIVER, "Rosan" insert, ¼–28 to ⅜–16	41–D–2967–750	4	60	Driving the locking ring on inserts.
DRIVER, "Rosan" insert, 5/16–24 to 7/16–20	41–D–2967–755	4	60	Driving the locking ring on inserts.
DRIVER, "Rosan" insert, ⅜–24 to ½–20	41–D–2967–760	4	60	Driving the locking ring on inserts.
DRIVER, "Rosan" insert, 7/16–20 to ⅝–18	41–D–2967–765	4	60	Driving the locking ring on inserts.
DRIVER, "Rosan" insert, ½–20 to ¾–16	41–D–2967–770	4	60	Driving the locking ring on inserts.
FIXTURE SET, reaming (accessory case)	41–F–2997–140	5, 36	46	Reaming and spot-facing starter drive gear bearing.
Composed of:				
ARBOR, reamer	7082251			
CUTTER, spot-facing	7082254			
FIXTURE ASSY	7082244			
JIG, drill	7082179			
REAMER	7082253			
FIXTURE SET, reaming (accessory case)	7082841	5, 36	46	Reaming and spot-facing ignition drive bevel gear bearings.
Composed of:				
ARBOR, reamer	7082845			
BUSHING, fixture	7082234			
CUTTER, spot-facing	7082242			
FIXTURE ASSY	7082842			
JIG, drill	7082177			
REAMER	7082238			
FIXTURE SET	41–F–2997–185	6	78	Reaming crankshaft and flywheel dowel pin holes.

FIXTURE SET, reaming (accessory case)	7082775	5, 36	46	Reaming and spot-facing accessory drive shaft and accessory driven shaft bearings.
Composed of:				
ARBOR, reamer	7082291			Arbor for reamers and cutters for accessory drive shaft bearings.
ARBOR, reamer	7082784			Arbor for reamer and cutter for accessory driven shaft bearings.
CUTTER, spot-facing	7082297			Spot-facing accessory drive gear bearing.
CUTTER, spot-facing	0782294			Spot-facing oil pump drive bevel gear bearing.
CUTTER, spot-facing	7082289			Spot-facing accessory driven shaft bearing.
FIXTURE ASSY	7082776			Reamer fixture.
FIXTURE ASSY	7082779			Pilot fixture for arbor 7082291.
BUSHING, pilot	7082277			Pilot for arbor 7802291.
JIG, drill	7082185			Guide for removing and replacing bearing pins.
JIG, drill	7082785			Guide for removing and replacing bearing pins.
JIG, drill	7082181			Guide for removing and replacing bearing pins.
REAMER ASSY	7082298			Spot-facing accessory drive shaft bearing (front).
REAMER	7082288			Reaming accessory driven shaft bearing (front).
REAMER	7082295			Reaming oil pump drive bevel gear bearing.
REAMER	7082296			Reaming accessory drive gear bearing.
REAMER	7082293			Reaming accessory driven shaft bearing.
REPLACER	7082786	5	46	Replacing oil pump drive bevel gear bearing.
GAGE AND COMPRESSOR	41–G–534–50	4, 60, 76	72, 89	Gaging piston ring gap and installing piston.
GAGE, thickness	41–G–415–175	4, 79	93	Setting valve rocker clearance.
KIT ASSY (engine stand)	41–K–106–505	8	25, 87	Assembly and disassembly of engine.
LIGHT, timing, complete w/battery and neon bulbs.	41–L–1439	4	94	Timing engine.

Table I. Special Tools and Equipment for Field and Depot Maintenance—Continued

Item	Identifying number	References		Use
		Fig.	Par.	
PROTECTOR (connecting rod)	41–P–2839–535	4, 25	41, 87	Protecting crankcase when cylinders are removed.
PLIERS, snap ring, external, removing and replacing, number 2.	41–P–1992–27	4	68, 70, 114	
PLIERS, snap ring, internal, removing and replacing, number 3.	41–P–1992–35	4	39, 64, 68, 70, 90	
PLIERS, snap ring, external, removing and replacing, number 4.	41–P–1992–28	4	47	
PLIERS, snap ring, internal, removing and replacing, number 5.	41–P–1992–36	4	37, 53	
PLIERS, snap ring, external, removing and replacing, number 6.	41–P–1992–49	4	92	
PULLER	41–P–2906–280	4, 19, 21, 23, 32, 33	39, 40, 45, 90	Removing accessory driven shaft support, fan drive gear support, generator adapter plate, and fuel pump drive adapter.
PULLER, main bearing cap	41–P–2942–200	4, 28	44	
REAMER, roughing	41–R–2254–565	4	55	Exhaust valve guide, valve stem hole.
REAMER, finishing	41–R–2254–515	4	55	Exhaust valve guide, valve stem hole.
REAMER, roughing	41–R–2254–550	4	55	Intake valve guide, valve stem hole.
REAMER, finishing	41–R–2254–500	4	55	Intake valve guide. valve stem hole.
REMOVER, guide, intake valve	41–R–2371–30	4, 47	55	
REMOVER, guide, exhaust valve	41–R–2371–15	4, 47	55	
REMOVER, helicoil inserting bar	41–R–2367–60	4		Helicoil replacement.
REMOVER, oil pump drive bevel gear bushing.	41–R–2369–535	4	46	
REMOVER KIT, valve seat inserts	41–R–2371–465	6, 49	55	Removing and installing valve seat inserts.
REMOVER AND REPLACER	41–R–2378–570	4, 62	71, 73	Piston rings.

REMOVER AND REPLACER	41–R–2378–602	4, 20	39, 90	Fan drive shaft.
REMOVER AND REPLACER, plug	41–R–2378–575	4, 17	37, 94	Removing and installing camshaft drive quill and oil transfer plug.
REPLACER, guide, exhaust valve	41–R–2390–473	4, 48	55	Installing exhaust valve guide.
REPLACER, guide, intake valve	41–R–2390–478	4, 48	55	Installing intake valve guide.
REPLACER, oil seal	41–R–2388–715	4	46, 47	Starter drive gear hub bearing oil seal.
REPLACER, oil seal	41–R–2392–995	4	47	Magneto drive driven gear.
SLING, crankshaft lifting	7082025	4, 29	44, 87	
SLING, engine and transmission	7082893	7	-------	Lifting engine and transmission, or engine only.
STAND, transport	7082923	9	-------	Engine and transmission, or engine only.
TAP, 14-mm	41–T–1290–500	4	-------	Helicoil insert.
TOOL, extracting	41–T–3092–321	4	-------	Helicoil replacement.
TOOL, inserting	41–T–3217–675	4	-------	Helicoil replacement.
TOOL, staking	41–T–3368–600	4	-------	Helicoil replacement.
WRENCH, box	41–W–872–710	4, 24	41, 89	Cylinder hold-down nut, ⅝ hex.
WRENCH, box	41–W–872–715	4, 24	41, 89	Cylinder hold-down nut, ¾ hex.
WRENCH, box, single end	41–W–1496–625	4	-------	Generator and starter nuts.
WRENCH, crowfoot	41–W–871–70	4, 11	26, 101	Ignition shielding.
WRENCH, crowfoot	41–W–3304–800	4, 11	26	Spark plug holding.
WRENCH, engine turning	41–W–906–125	4	12, 41, 90, 94	
WRENCH, "Rosan" insert	41–W–1536–390	4	60	Installing ¼–28 to ⅜–16 inserts.
WRENCH, "Rosan" insert	41–W–1536–393	4	60	Installing 5/16–24 to 7/16–20 inserts.
WRENCH, "Rosan" insert	41–W–1536–396	4	60	Installing ⅜–24 to ½–20 inserts.
WRENCH, "Rosan" insert	41–W–1536–399	4	60	Installing 7/16–20 to ⅝–18 inserts.
WRENCH, "Rosan" insert	41–W–1536–402	4	60	Installing ½–20 to ¾–18 inserts.
WRENCH, spanner, hook, adjustable, ¾ in to 2 in.	41–W–3249–900	4	80	Ignition harness.
WRENCH, spark plug inserting	41–W–3306–500	4	101	
WRENCH, socket, double end	41–W–3727–33	4, 34	45, 90	Oil pressure control valve and oil filter by-pass valve.

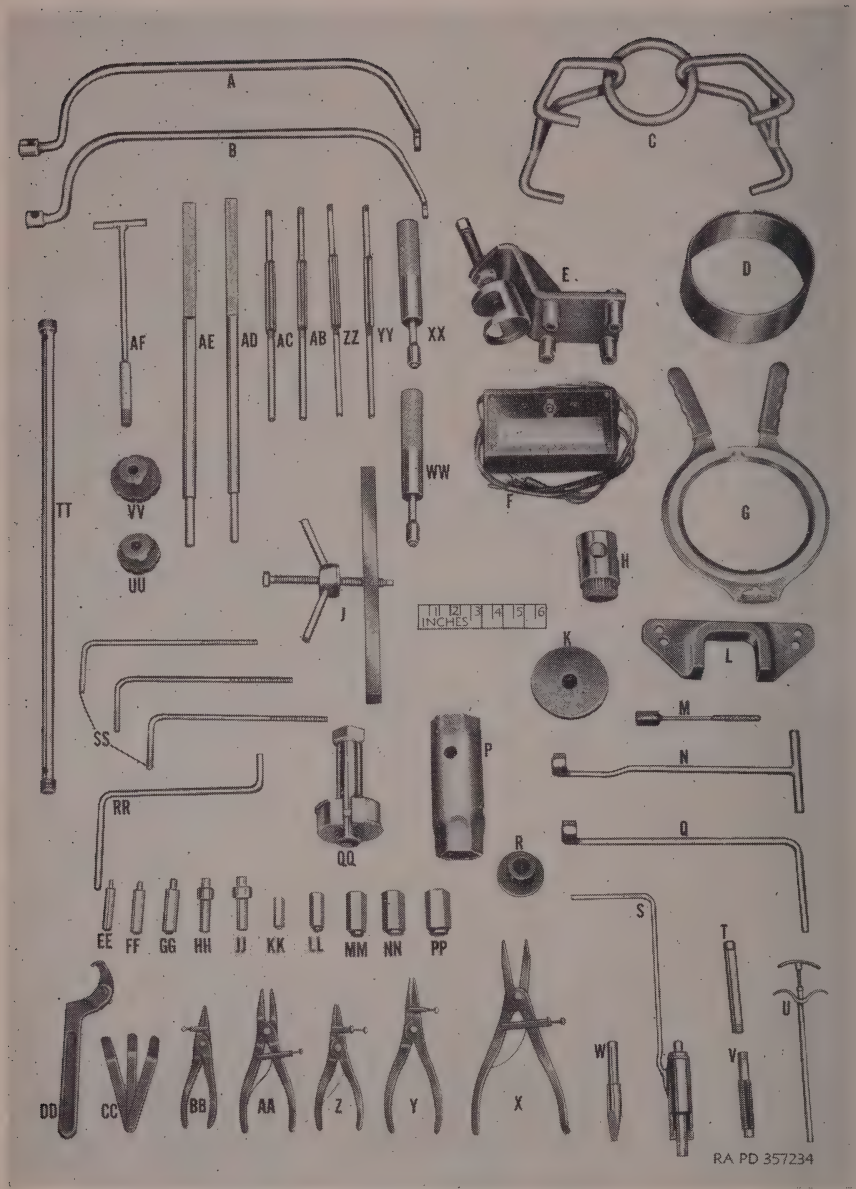

Figure 4. Special tools and equipment.

A—WRENCH, BOX (5/8 HEX)—41–W–872–710
B—WRENCH, BOX (3/4 HEX)—41–W–872–715
C—SLING, CRANKSHAFT LIFTING—7082025
D—GAGE AND COMPRESSOR, PISTON RINGS—41–G–534–50
E—COMPRESSOR, VALVE SPRING—41–C–2558–900
F—LIGHT, TIMING—41–L–1439
G—REMOVER AND REPLACER, PISTON RINGS—41–R–2378–570
H—WRENCH, ENGINE TURNING—41–W–906–125
J—PULLER, MAIN BEARING CAP—41–P–2942–200
K—REPLACER, OIL-SEAL AND BEARING—41–R–2388–715
L—PROTECTOR, CONNECTING ROD—41–P–2839–535
M—WRENCH, SPARK PLUG INSERTING—41–W–3306–500
N—WRENCH, CROWFOOT—41–W–871–70
P—WRENCH, SOCKET—41–W–3727–33
Q—WRENCH, CROWFOOT—41–W–3304–800
R—REPLACER, OIL SEAL—41–R–2392–995
S—TOOL, INSERTING—41–T–3217–675
T—TOOL, STAKING—41–T–3368–600
U–REMOVER, HELICOIL—41–R–2367–60
V—TAP, 14-mm—41–T–1290–500
W—TOOL, EXTRACTING—41–T–3092–321
X—PLIERS, SNAP RING, INTERNAL (No. 5)—41–P–1992–36
Y—PLIERS, SNAP RING, EXTERNAL (No. 6)—41–P–1992–49
Z—PLIERS, SNAP RING, EXTERNAL (No. 4)—41–P–1992–28
AA—PLIERS. SNAP RING, INTERNAL (No. 3)—41–P–1992–35
BB—PLIERS, SNAP RING, EXTERNAL (No. 2)—41–P–1992–27
CC—GAGE, THICKNESS—41–G–415–175
DD—WRENCH, SPANNER—41–W–3249–900
EE—DRIVER, "ROSAN" INSERT—41–D–2967–750
FF—DRIVER, "ROSAN" INSERT—41–D–2967–755
GG—DRIVER, "ROSAN" INSERT—41–D–2967–765
HH—DRIVER, "ROSAN" INSERT—41–D–2967–760
JJ—DRIVER, "ROSAN" INSERT—41–D–2967–770
KK—WRENCH, "ROSAN" INSERT—41–W–1536–390
LL—WRENCH, "ROSAN" INSERT—41–W–1536–393
MM—WRENCH, "ROSAN" INSERT—41–W–1536–399
NN—WRENCH, "ROSAN" INSERT—41–W–1536–396
PP—WRENCH, "ROSAN" INSERT—41–W–1536–402
QQ—REMOVER, BEARING—41–R–2369–535
RR—WRENCH, BOX—41–W–1496–625
SS—PULLERS—41–P–2906–280
TT—REMOVER AND REPLACER—41–R–2378–602
UU—BUSHING, PILOT—41–B–2181–150
VV—BUSHING, PILOT—41–B–2181–175
WW—REPLACER GUIDE, EXHAUST VALVE—41–R–2390–473
XX—REPLACER GUIDE, INTAKE VALVE—41–R–2390–478
YY—REAMER, FINISHING—41–R–2254–500
ZZ—REAMER, ROUGHING—41–R–2254–550
AB—REAMER, FINISHING—41–R–2254–515
AC—REAMER, ROUGHING—41–R–2254–565
AD—REMOVER GUIDE—41–R–2371–30
AE–REMOVER GUIDE—41–R–2371–15
AF—REMOVER and REPLACER, plug—41–R–2378–575

Figure 4—Continued.

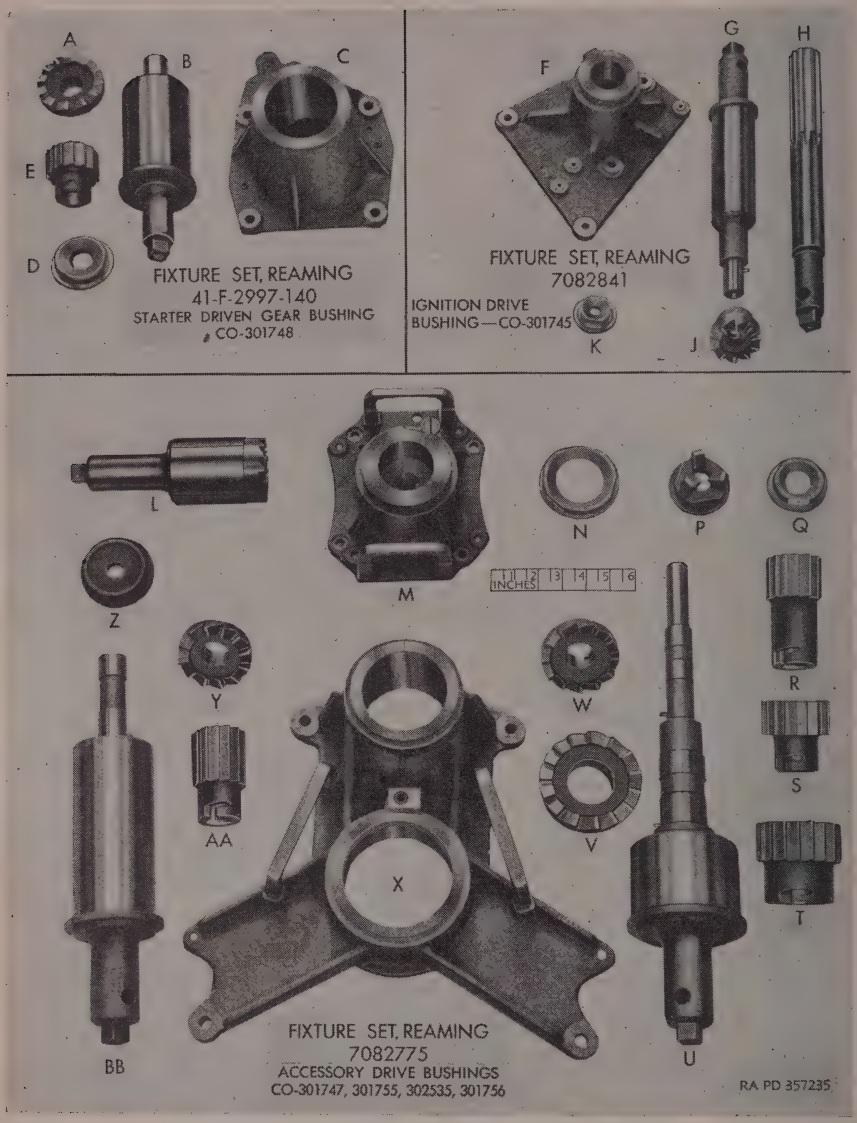

Figure 5. Special tools and equipment.

A–CUTTER, SPOT-FACING—7082254
B—ARBOR—7082251
C—FIXTURE—7082251
D—JIG, DRILL—7082179
E—REAMER—7082253
F—FIXTURE—7082842
G—ARBOR—7082845
H—REAMER—7082238
J—CUTTER, SPOT-FACING—7082242
K—JIG, DRILL—7082177
L—REAMER ASSY—7082298
M—FIXTURE—7082779
N—JIG, DRILL—7082185
P—JIG, DRILL—7082785
Q—JIG, DRILL—7082181
R—REAMER—7082288
S—REAMER—7082295
T—REAMER—7082296
U—ARBOR—7082291
V—CUTTER, SPOT-FACING—7082297
W—CUTTER, SPOT-FACING—7082294
X—FIXTURE—7082776
Y—CUTTER, SPOT-FACING—7082289
Z—REPLACER—7082786
AA—REAMER—7082293
BB—ARBOR—7082784

Figure 5—Continued.

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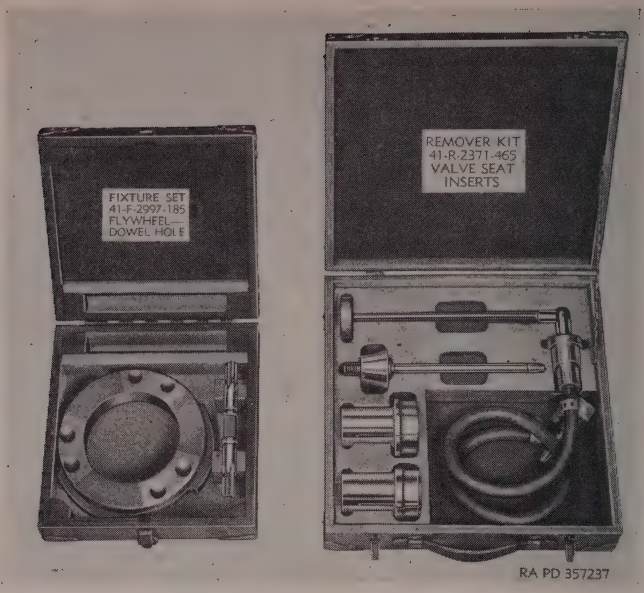

Figure 6. Special tools and equipment.

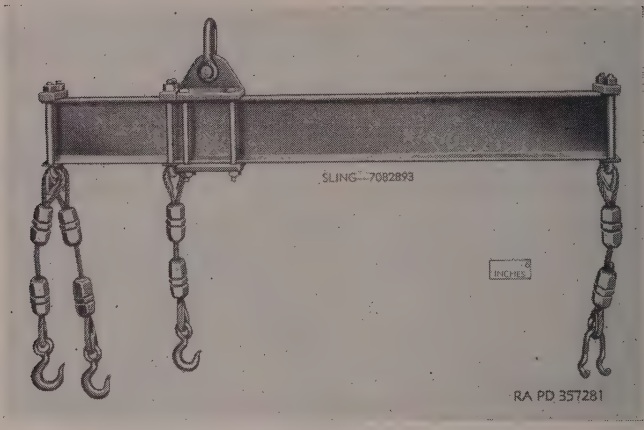

Figure 7. Special tools and equipment.

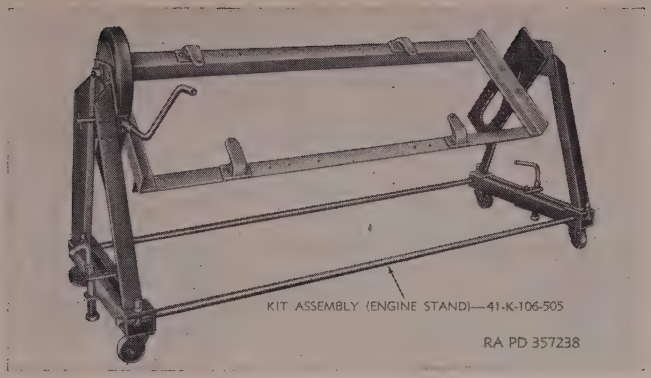

Figure 8. Special tools and equipment.

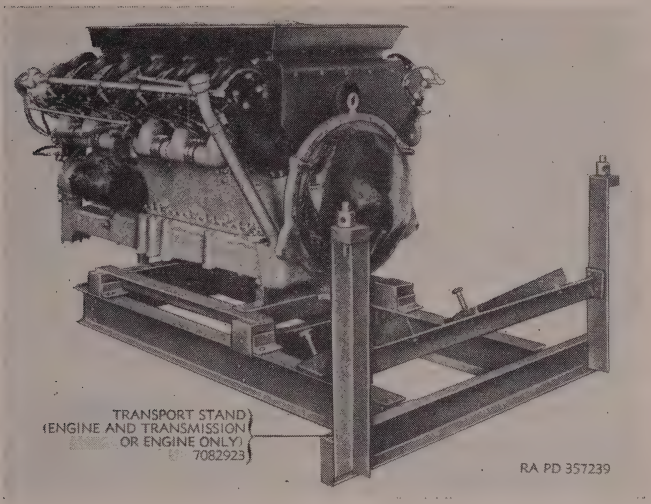

Figure 9. Special tools and equipment.

CHAPTER 3

TROUBLE SHOOTING

Note. Information in this chapter is for use of ordnance maintenance personnel in conjunction with and as a supplement to the trouble shooting section in the pertinent operator's manual. It provides the continuation of instructions where a remedy in the operator's manual refers to ordnance maintenance personnel for corrective action.

Section I. GENERAL

9. Purpose

Operation of a deadlined vehicle without a preliminary examination can cause further damage to a disabled component and possible injury to personnel. By careful inspection and trouble shooting, such damage and injury can be avoided and, in addition, the causes of faulty operation of a vessel or component often can be determined without extensive disassembly.

10. General Instructions and Procedures

This chapter contains inspection and trouble shooting procedures to be performed while a disabled component still is mounted in the vehicle and after it has been removed.

a. The inspections made while the component is mounted in the vehicle are visual for the most part and are to be performed before attempting to operate the vehicle. The object of these inspections is to avoid possible damage or injury and also to determine the condition of, and when possible, what is wrong with the defective component.

b. The trouble shooting performed while the component is mounted in the vehicle is that which is beyond the normal scope of organizational maintenance. Check the trouble shooting section of TM 9–718, or any other pertinent operator's manual, to be sure the trouble is not a defect normally corrected by the using organization, then proceed as outlined in this chapter. These trouble shooting operations are used to determine if the fault can be remedied without removing the component from the vehicle and also, when subsequent removal is necessary, to indicate when repair can be made without complete disassembly of the component.

c. Inspection after the component is removed from the vehicle is performed to verify the diagnosis made when the component was in

the vehicle, to uncover further defects, or to determine faults if the component alone is received by the ordnance establishment. This inspection is particularly important in the last case because it often is the only means of determining the trouble without completely disassembling the component.

d. Trouble shooting a disabled component after it has been removed from the vehicle consists of subjecting it to tests on a dynamometer. This chapter discusses those symptoms which can be diagnosed by using the testing equipment and interprets the results in terms of probable causes.

Section II. ENGINE

11. General

Most engine troubles actually are accessory troubles. The trouble shooting portion of TM 9–718, or of other pertinent operator's manuals, normally will cover trouble shooting of all engine accessories while mounted on the engine. This section covers only those troubles which can develop within the engine itself.

12. Procedures

a. Seizure of Part:. When an engine cannot be turned over by hand or with the starter, seizure of parts is the cause. The seizure generally can be isolated to the accessory case or the power section by removing the accessory drive shaft (par. 39*d*). After removing the shaft, attempt to turn the engine by hand at both the flywheel and the power take-off. If the seizure is in the power section, turning should be free at the power take-off. If it is in the accessory case, turning should be free at the flywheel. Remove the accessory case from the power section and perform necessary repairs.

Caution: Exercise great care in deciding what inspection and repairs must be performed. Parts in the nonseized section may be strained or bent and require replacement, or presence of chips may require a complete teardown and cleaning of the engine lubricating system.

b. Gear Failures. Gear and driveshaft failures generally can be isolated by a systematic check of the affected gear train. Methods of locating these failed gears is covered under the individual systems. Gear failure repairs frequently can be confined to replacement of the damaged parts.

Caution: Exercise great care in deciding what repairs must be made. Disassembly and cleaning of part or all of the engine may be necessary due to contamination of the engine lubricating system or moving parts with chips.

c. Noise. Engine noises can be caused by worn, broken, or improperly adjusted parts and by lack of lubrication. Ability to isolate trouble causing a noise is a matter of experience and even then is somewhat inaccurate. When noise occurs, shut down engine immediately for investigation. Some of the more common noises and their cause are—

(1) *Grinding noise.* Turn the engine by hand. If it is somewhat tight and the grinding persists, a bushing or bearing probably is failing. Refer to *a* above.

(2) *Sharp tapping noise.* A defective rocker or incorrect valve clearance will produce this sound. Start the engine and listen through a short piece of pipe pressed against the rocker covers. The tapping from the defective unit will be much sharper and louder than from the others.

(3) *Heavy clattering at speeds below 350 rpm.* This noise is caused by clattering of the torsional vibration damper counterweights and is a normal noise. It will disappear at higher speeds.

d. Ignition System.

(1) *Preliminary instructions.* Most ignition system defects are covered in the pertinent operator's manual. However, failure or seizure of one or more gears in the magneto drive train would result in the magnetos on one or both sides of the engine not firing.

(2) *Procedure.* Remove the magnetos and rotate the engine with turning wrench (41–W–906–125). If the engine will not rotate, refer to *a* above. If one or more of the magneto drive gears fails to rotate, see if the other accessories rotate and use the following applicable procedure:

(*a*) *Other accessories do not rotate.* Remove the accessory case and locate the damaged gears or shafts. Before repairing damage, refer to *b* above.

(*b*) *Other accessories turn.* Remove the magneto adapter housings and inspect their gears. See if the ignition drive driven bevel gears rotate with the engine. If they do not, remove the accessory case and inspect for gear failure. Before repairing or replacing damaged gears, refer to *b* above.

e. Fuel System.

(1) *Preliminary instructions.* Most fuel system defects are covered in the pertinent operator's manual. A failure in the gear train will result in nonoperation of the fuel pumps.

(2) *Procedure.* Remove the fuel pumps and fuel pump adapter. Inspect the fuel pump drive gears and cams for failure. Refer to *b* above for repairs. If the gears appear to be all right, examine the pinned joint between the starter drive gear hub

and the fuel pump drive gear (par. 47*b* (14)). Repair, as necessary, if the joint is defective. If the joint is all right, remove the accessory case and locate the gear failure. Refer to *b* above for repairs.

f. Air Intake, Manifolds, and Valves.

(1) *Preliminary instructions.* Most induction system difficulties are covered in the pertinent operator's manual. Difficulties that are not covered therein and the methods of locating them are listed under (2) below.

(2) *Procedure.* Remove the rocker box covers and examine the camshafts and rockers for damage. Follow whichever of the the following conditions that applies:

(*a*) *Camshaft damaged.* If the camshaft is damaged, do whichever of the following that applies:

1. Camshaft bearing or journal damaged. Repair or replace damaged parts.

2. Camshaft lobe damaged. Repair or replace damaged component. Inspect rocker roller for freedom of rotation and damage. Replace any defective rocker.

3. Camshaft broken. Replace with new camshaft.

(*b*) *Rocker damaged.* Replace the damaged rocker assembly. Inspect the corresponding camshaft lobe for damage, and repair or replace camshaft as necessary. Check for a stuck valve ((*c*) below), and for clogged lubricating passages to the rocker roller, if frozen.

(*c*) *Valve stuck.* Turn the engine with the turning wrench (41–W–906–125) and observe if all valves open and close satisfactorily. If any valves are stuck open, it will be readily apparent. Remove the cylinder and make the necessary repairs and parts replacements. A stuck valve often will damage the rocker and sometimes the camshaft. Repair the valve difficulty and inspect the rocker and camshaft for conformance to serviceability standards (par. 138)).

(*d*) *No damage visible.* Turn the engine with the turning wrench (41–W–906–125) and observe if the camshafts rotate. If they do not, remove the camshaft gear housing covers and examine the gears for damage. If they are all right, remove the camshaft drive quills (fig. 17) and inspect for damage. If they are all right, remove the accessory case and locate the damaged gears. Before repairing or replacing damaged gears, refer to *b* above.

g. Starting System.

(1) *Preliminary instructions.* Most defects are covered in the pertinent operator's manual. A failure or seizure in the gear train are other difficulties that may occur.

(2) *Procedures.* Turn the engine with the turning wrench (41–W–906–125). If it cannot be turned, refer to *a* above. If it turns, attempt to crank engine with starter. If the entire engine does not crank, remove the fuel pump drive shaft adapter assembly (fig. 33) from the engine and examine for damage to the starter drive gear. If none is evident, remove the accessory case and locate the damaged gear. Before repairing or replacing any gear, refer to *b* above.

h. Engine Low in Power. Stop engine and proceed as in *c*(1) above. If that is not the cause, trouble-shoot as outlined in the pertinent operator's manual and in *d*, *e*, and *f* above.

i. Engine Misfires and Runs Rough. Trouble-shoot as outlined in the pertinent operator's manual and in *d*, *e*, and *f* above.

j. Engine Fails To Start. Refer to pertinent operator's manual and to *d*, *e*, and *f* above.

k. One Bank of Cylinders Fails To Fire. Proceed as in *j* above.

l. Engine Lubrication System Defective.

(1) *Preliminary instructions.* Make the checks outlined in the pertinent operator's manual. If the trouble is not isolated, proceed as in (2) below.

(2) *Procedures.*

(*a*) *Low oil pressure.* Obstructed oil galleries or worn or burned out bushings and bearings could cause this condition. If the obstructing material in the oil gallery is something that might be throughout the rest of the engine, rebuild the entire engine; otherwise, remove the obstruction. If worn parts are the cause, rebuild engine.

(*b*) *Excessive oil consumption.* Excessive oil consumption caused by worn or scored engine parts should be diagnosed carefully to determine whether a complete engine rebuild or only a cylinder, piston, and piston ring overhaul is required.

m. Generating System. If tests in the pertinent operator's manual do not isolate the trouble, see if the generator drive gear turns when the engine is cranked. If it does not turn, remove it for inspection. If damaged, repair or replace. If the gear is all right, remove the accessory case to inspect for damaged gears. Before repairing or replacing any damaged gears, refer to *b* above.

CHAPTER 4

ENGINE

Section I. DESCRIPTION AND DATA

13. Lubrication System

a. Two positive displacement gear pumps—scavenge and pressure—supply oil to the lubricating system. This dual pump is enclosed in a single housing mounted on the lower side of the accessory case. The scavenge pump transfers oil from the large compartment of the oil pan to the small compartment at the accessory end, which serves as a reservoir for the pressure pump. The baffle between the compartments is constructed to permit oil flow into the small compartment from the larger when the flywheel end is the higher, and to retain a certain portion of the oil when the accessory end is the higher. With the scavenge pump constantly transferring oil to the small compartment, the pressure pump is assured of an adequate supply when the vehicle is on grades. In normal operation, the oil passes from the pressure pump through external oil coolers and returns to the engine through an oil filter. The oil flow is controlled by three valves, an oil cooler bypass valve, a pressure control valve, and an oil filter bypass valve (fig. 10).

b. The oil cooler bypass valve is located in the upper portion of the filter housing (fig. 58). This is a spring-balanced valve, subject to pump delivery pressure on one side and to return line pressure on the other. Should oil flow through the cooler be restricted for any reason, the return line pressure is reduced. When the differential pressure reaches 50 psi, the valve opens and the oil passes directly to the return line.

c. The oil pressure control valve, in the inlet to the engine oil passages, maintains the desired oil pressure to the engine. Excess oil is passed directly to the sump. Both the oil filter bypass valve and the oil pressure control valve are located in the lower right-hand portion of the accessory case (fig. 31).

d. The oil filter bypass valve is a balanced valve similar to the oil cooler bypass valve. Should the filter become obstructed, this valve opens when the differential pressure reaches 50 p. s. i., and the oil is delivered directly to the engine.

e. Drilled passages in the accessory case provide lubrication to all bushings in the case, and another passage leads to the oil gallery in

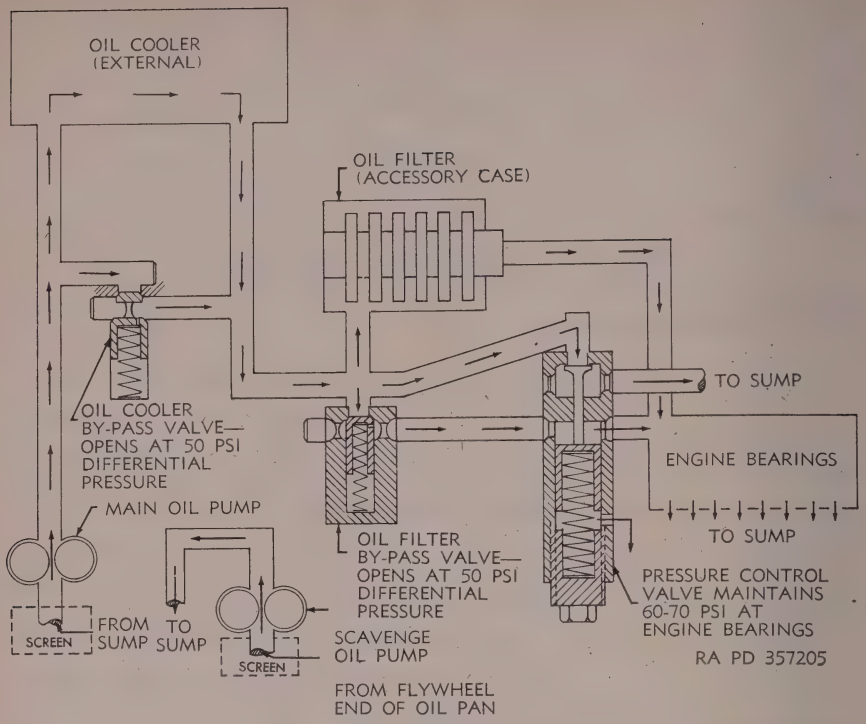

Figure 10. Oil flow diagram

the crankcase. Drilled passages from the gallery through the crankcase webs convey oil to the main bearings. Oil passages from each crankshaft journal to the crankpins lubricate the connecting rod bearings. Cylinder bores, pistons, rings, and piston pins are lubricated by oil thrown from the connecting rods.

f. Connecting passages in the accessory case admit oil under pressure to the hollow camshafts. Drilled holes in each camshaft journal convey oil through connecting passages to the rocker shafts and rocker arm bushings. Throw-off oil lubricates the valve stems. Additional lubrication is provided for the exhaust valve stems by oil streams from drilled passages in the camshaft bearings.

g. External drain lines (fig. 15) return oil from the rocker boxes to the oil pan. The camshaft drive gear cases drain back through the quill housings.

14. Hydraulic Governor

The hydraulic governor is provided to maintain engine speed below predetermined limits regardless of engine load. For additional description of the hydraulic governor, see paragraph 113.

15. Crankcase and Oil Pan

a. The crankcase (fig. 52) is a one-piece aluminum alloy casting upon which two banks of six individual cylinder assemblies are secured. The cylinders are mounted on machined pads on the upper side of the crankcase in a 90° upright "V" position. Seven main bearings for the crankshaft are held by transverse webs. The lower halves of the main bearings are held in place by individual forged aluminum alloy caps. The bottom of the crankcase provides for installing the crankshaft, the opening being large enough to allow the crankshaft to be installed with all the connecting rods attached.

b. An oil gallery is located in the right side of the crankcase casting. Oil passages are drilled through the webs to connect the gallery with each main bearing. In this manner, the gallery line supplies oil under pressure to each one of the crankshaft main bearings.

c. The oil pan is a one-piece aluminum alloy casting. Studs are set in the flange for securing the pan to the crankcase. The pan is divided into two compartments. The smaller compartment is located at the accessory end and forms the reservoir for the oil pressure pump. The compartment is constructed to allow oil to flow into it from the larger compartment when the flywheel end is the higher, and prevent it from flowing out when the accessory end is the higher. A screened drain sump is provided in each compartment.

16. Main Bearings

Main bearings are fitted with replaceable bearings (fig. 52). These bearings are precision type, steel-backed, faced with a special bearing alloy. The center main bearing is double flanged, the flanges faced with the bearing metal. This bearing takes all of the crankshaft thrust. The bearings are split on the diameter, each half identical. Each bearing is provided with a tang at the joint or split surface. These tangs seat in corresponding recesses in the main bearings to prevent turning. An oil hole drilled through the bearing, at approximately 45° from the joint line, registers with an oil groove cut in the main bearing of the crankcase. The bearing face has an annular groove which registers with the oil hole in the crankshaft journal.

17. Crankshaft

a. The crankshaft (fig. 52) is a steel forging having seven main bearing journals and six crank throws. The counterweights are forged integrally with the shaft. An integrally forged flange is provided for the flywheel mounting. A flanged hub is assembled permanently on the accessory end for the mounting of the vibration damper counterweights.

b. All crankpin and main bearing journals are hollow to reduce

weight. Holes are drilled diagonally through each main bearing journal and extend through the crank cheek and the crankpin. A steel tube, extending from the outer surface of the crankpin to the outer surface of the main bearing journal, provides a direct passage for oil, under pressure, to the connecting rods.

c. The finished crankshaft is balanced statically and dynamically.

18. Connecting Rods and Bearings

Connecting rods (fig. 55) are I-section type with tapered shanks and are machined from steel forgings. Bronze piston pin bearings are pressed into the small end of each connecting rod. The bearings then are diamond-bored to the finished size. Connecting rod bearings are the split, precision type. They are steel-backed, similar to the main bearing liners. A small tang on each half bearing engages recesses in both rod and cap to prevent turning. Bearings are secured further by the pinch loading of the cap.

19. Pistons, Pins, and Rings

a. Pistons (fig. 55) are of the aluminum, solid skirt type. The piston skirt is cam ground and tapered to provide accurate fit in the cylinder when at operating temperature. The pistons are reinforced with piston pin bosses which extend to the crown of the piston.

b. Pistons have four rings, the top two rings being compression rings, while the third and fourth are oil control rings. The upper two rings are chrome faced.

c. Piston pins are tubular and full-floating. Domed aluminum plugs are inserted in each end of the piston pin to centralize the pin and to prevent scoring or damage to the cylinder wall.

20. Cylinders and Valves

a. The cylinders are arranged in two banks (par. 5), the number one cylinder being at the accessory end (figs. 1 and 45). Each cylinder is a separate unit. The cylinder barrel is an alloy steel shell around which is cast an aluminum muff. The entire muff is finned for air cooling. A finned, aluminum cylinder head, internally threaded, engages external threads on the cylinder barrel. The assembly is made permanent by shrinkage fit. The valve seat inserts are installed in machined recesses by heating the cylinder head and cooling the inserts. The inserts may be removed for replacement by use of a special remover kit supplied for that purpose (par. 55). Valve stem guides are bronze and are replaceable. An outer extension of the cylinder head encloses a recess in which the valve springs, rocker arms, and rocker shafts are assembled.

b. The camshaft bearing cap and valve rocker support bracket hold the rocker shafts. The cap and bracket are dowelled to the cylinder head and the camshaft bearing is bored with caps in place. Therefore, the caps are not interchangeable and must remain as parts of the cylinder assemblies. One camshaft bearing is provided in each cylinder head. Counterbores in the rocker box walls and covers accommodate the intercylinder connectors.

c. The valve stems extend into the rocker boxes. Three springs, compressed between two retainers and secured to the valve stems by split cone-shaped locks, hold the valves to their seats. The exhaust valves are sodium-cooled. Valve clearance adjusting screws are mounted in the valve rocker ends.

d. Forged steel valve rockers with roller cam followers are used. The rollers are specially hardened and honed to provide an extremely smooth and permanent wearing surface. Hollow rocker shafts and drilled passages in the arms convey oil to all moving parts.

e. Rocker box covers are not entirely interchangeable. End rocker box covers are machined and tapped for the attachment of the camshaft gear housings and end cover plates. Intermediate cylinder covers are not so machined. End covers are interchangeable and intermediate cylinder covers may be interchanged.

21. Camshaft

a. A hollow camshaft (fig. 41) is mounted on each bank of cylinders. Tubular intercylinder connectors enclose the camshaft (fig. 77). The joints at the cylinder heads are sealed by "O" ring gaskets.

b. Each camshaft is driven by bevel gears through separate, inclined drives from a bevel gear in the accessory case. The inclined drive quills can be removed to permit separate rotation of the camshafts for engine timing.

22. Accessory Case

a. The accessory case (figs. 30 and 31) is an aluminum alloy casting in which are assembled the gear trains necessary to operate the camshafts, magnetos, oil pump, fuel pumps, starter, generator, and the cooling fans. Where gear loads require, bearings are fitted with bushing-type bronze bearings which are replaceable. Numerous drilled passages supply pressure lubrication to all bearings.

b. The accessory case is secured to the crankcase on studs in the crackcase flange and is alined by four dowel pins. Drive connection from the crankshaft is through a splined accessory drive shaft (fig. 31), which is installed after the case is assembled to the crankcase.

23. Data

Cylinder bore	5.75 in
Piston stroke	5.75 in
Piston displacement	1791.75 cu-in
Compression ratio	6.5 : 1
Valve timing setting	Intake closes 50° after bottom center with 0.100-in. clearance
Valve clearance (cold engine)	
Intake	0.007 in
Exhaust	0.020 in
Valve events (with cold clearances)	
Intake open	30° before top center
Intake closed	70° after bottom center
Exhaust open	70° before bottom center
Exhaust closed	30° after top center
Ignition timing	Automatic advance, set 10° before top center
Firing order	1R, 2L, 5R, 4L, 3R, 1L, 6R, 5L, 2R, 3L, 4R, 6L
Accessory drive ratios	
Cooling fans	1.78 crankshaft speed
Tachometer drive	0.5 crankshaft speed
Generator	2.56 crankshaft speed
Magnetos	0.5 crankshaft speed
Power take-off	1.00 crankshaft speed
Governor	1.27 crankshaft speed
Starter	1.15 crankshaft speed
Fuel pump	0.58 crankshaft speed
Spark plug gap	0.011–0.014 in
Accessories—number of each	
Generator	1
Starter	1
Magnetos	4
Spark plugs	24
Carburetors	2
Fuel pumps	2
Governor	1
Generator output	150 amp, 28.5 v

Section II. PREPARATION OF ENGINE FOR REBUILD

24. General

a. Engines removed from vehicles for rebuild must be thoroughly cleaned, drained, and stripped of accessories. Refer to pertinent operator's technical manuals for procedures on removal of the engines from vehicles.

b. Transmit the accessories to proper department for inspection and rebuild.

25. Cleaning and Draining

a. Cleaning. Before attempting any repair or rebuild operations, the engine must be thoroughly cleaned. This can be done best with

the engine mounted on the engine stand kit assembly (41–K–106–505). Be certain that all openings are securely closed or covered before cleaning. Use water under pressure to remove as much mud and dirt as possible. Use a stiff brush and dry-cleaning solvent or volatile mineral spirit paint thinner to remove remaining grease and dirt.

b. Draining. Break locking wires and unscrew plugs from the oil sump screen housings (fig. 52). Drain oil pan.

26. Removal of Accessories

a. Carburetors.

(1) Disconnect electrical connections from the degassers and fuel supply lines. Disconnect, at the carburetor, vent lines from the ignition harness, magnetos, starter, and the breather line at the right carburetor. Disconnect carburetor control rods.

(2) Remove bolts holding the carburetors to the intake hot-spot manifolds, lift off carburetors, and strip off gaskets.

b. Fuel Pumps. Disconnect both fuel supply lines from fuel pumps (fig. 12). Remove lock nuts, nuts, and washers from fuel pump mounting adapter and remove adapter with pumps assembled. Strip off gasket.

c. Oil Filter Housing. Remove lock nuts, nuts, and washers holding housing to accessory case and remove.

d. Magnetos and Booster Coils.

(1) Remove cables between booster coils and magnetos.

(2) Detach distributor caps from magnetos. Remove mounting nuts and pull magnetos from magneto adapters.

(3) Remove nuts holding booster coils to their mounting pads and lift off coils.

e. Governor.

Note. The engine shrouds and the front cooling fan must be removed to provide access to the governor (pars. 27 and 28).

The governor is mounted on three studs on the front side of the forward fan tower (fig. 3). Remove holding nuts and pull governor from fan tower together with adapter and governor driven bevel gear. Discard gaskets. Later engines will have an external oil line to the governor which must be disconnected before governor removal.

f. Ignition Harness.

(1) Disconnect spark plug cables. Hold spark plugs from turning with crowfoot wrench (41–W–3304–800), and detach shielding nut with crowfoot wrench (41–W–871–70) (fig. 11).

(2) Disconnect starter vent line at starter (fig. 12).

(3) Both harnesses are supported above cylinders 1, 3, 4, and 6 by spacers and secured by bolts. Remove bolts and lift off harness.

g. Starter. Remove lock nuts and nuts securing starter to accessory case (fig. 12), and lift off starter.

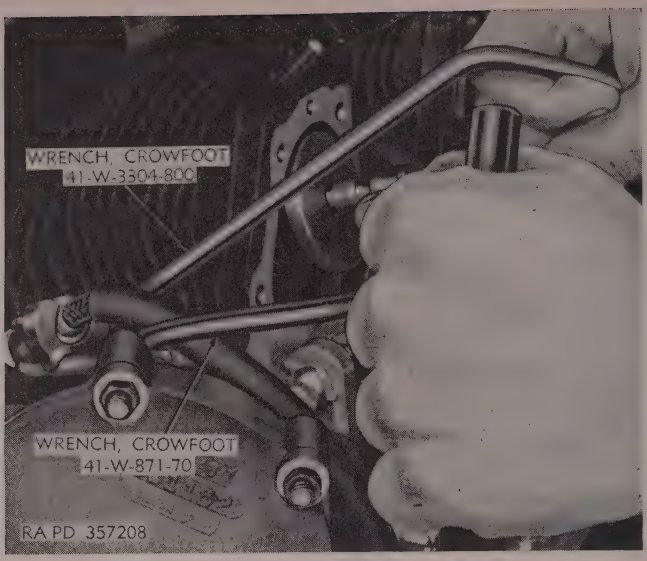

Figure 11. Disconnecting spark plug cables.

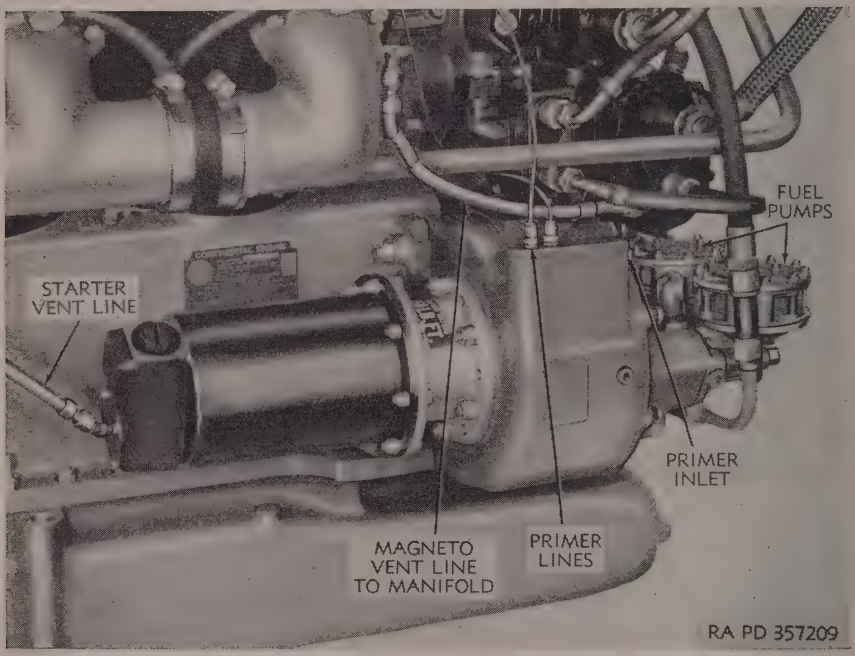

Figure 12. Starter and fuel pumps—installed.

h. Generator. The generator is mounted on studs fixed in a mounting plate. This plate is secured to the accessory case by five bolts extending through the case. Support generator and back out bolts (fig. 13). Pull generator straight out from case until driving spline is free.

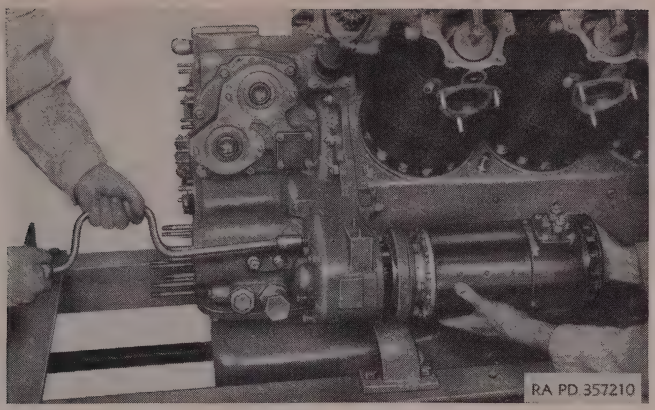

Figure 13. Removing generator.

Section III. DISASSEMBLY OF STRIPPED ENGINE INTO SUBASSEMBLIES

27. Removal of Engine Shrouds (fig. 14)

a. General. With the exception of the nuts holding the top engine shroud plate (L) to the cylinder heads, all shroud fasteners are lock nut and bolt type. Lock nuts are riveted to the inner sides of the shroud plates and the attached plates are secured with hex-head bolts installed from the outside.

b. Remove Fan Vane Housing Assemblies. Disengage bolts holding each vane assembly (A) to top shroud plates and lift off assemblies.

c. Remove Top Plates and Covers. Disengage bolts securing two exhaust manifold hole cover plates (C) and two top fan shroud plates (B and D).

d. Remove Flywheel End Shroud Plate. Remove bolts holding end plate (F) to top engine shroud plate (L), and lift plate up from spring clips on crankcase.

e. Remove Accessory End Shroud Plates. Disconnect two governor links from control shaft levers. Disconnect primer line clips. Remove bolts securing small end cover plate (N) and remove plate. The right and left end plates (M and P) are removed by detaching at top and lifting them from spring clips on crankcase.

f. Remove Top Engine Shroud Plate.

Note. Cooling fans, fan rotor housings, and exhaust manifolds, must be removed before removal of top engine shroud plate (L) (pars. 28 and 30).

Remove nuts from cylinder head studs and lift off top plate. Five intercylinder hinged covers (K) are attached to each side of top plate. They need not be detached except for replacement of a damaged cover. To detach, push one end of spring-loaded hinge pin out of its bearing and remove cover.

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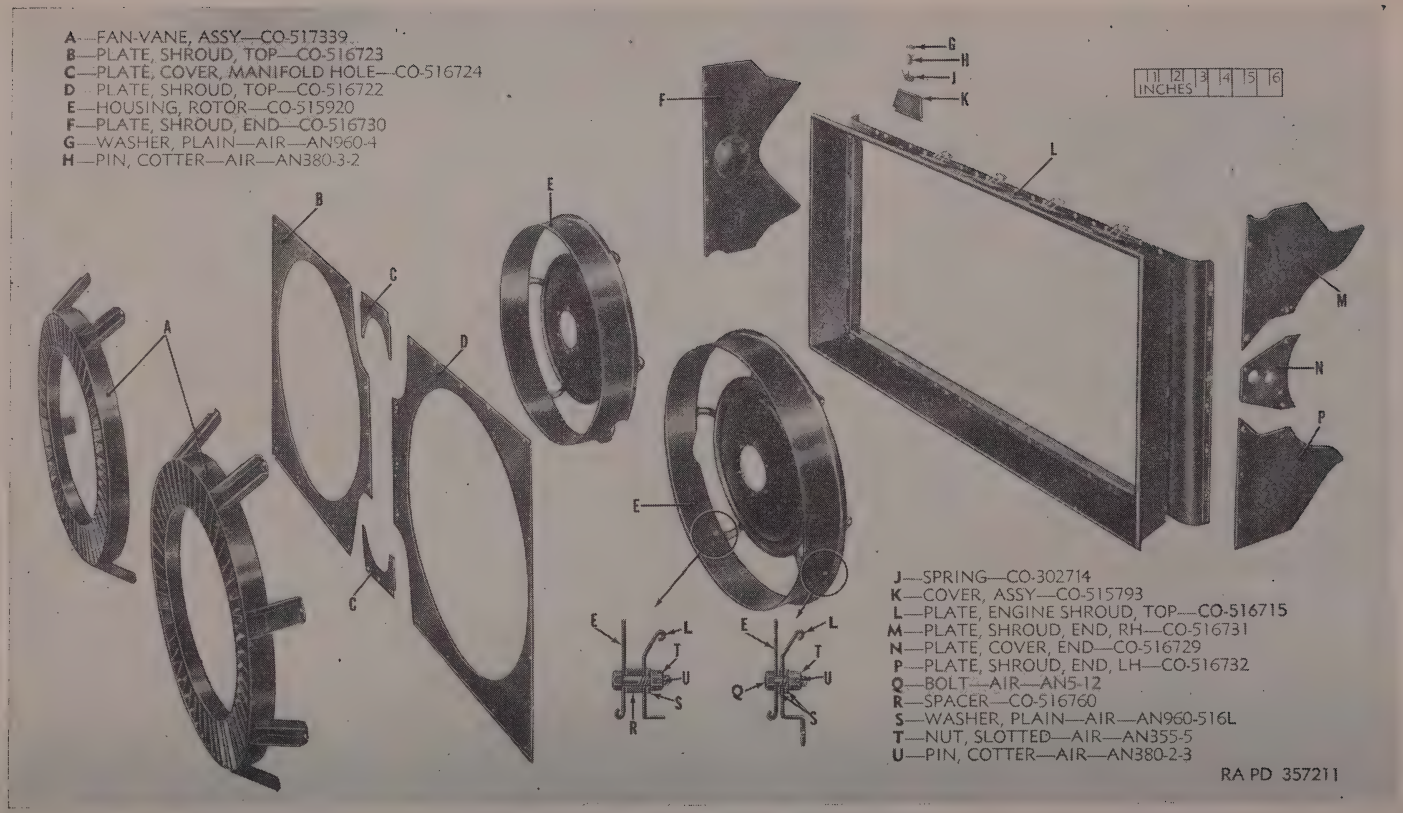


Figure 14. Engine shrouds—exploded view.

28. Removal of Cooling Fans and Fan Driving Housings (figs. 3, 43, and 44)

a. Remove three machine screws holding vertical shaft cover and lift off cover.

b. Pull cotter pin and remove slotted nut holding fan; pull fan off the splined drive shaft.

c. Remove nuts from fan drive housing studs and lift off rotor housing.

Note. On most engines, the fan rotor housings are secured to the top engine shroud plate by three bolts and the necessary spacers.

d. Remove nuts from base flanges and lift drive housings off the studs.

29. Removal of Breather Lines

a. Loosen hose connection and pull breather line from elbow in accessory case. Loosen hose connection at manifold hot-spot end and remove line.

b. Loosen hose connections on breather line, between crankcase and oil filler at crankcase, and pull hose off adapter. Remove nuts holding oil filler to oil pan and detach oil filler bracket from cylinder head. Remove oil filler with breather lines attached.

30. Removal of Exhaust Manifolds

Remove self-locking nuts holding manifold flanges to cylinders and lift off manifolds. Discard gaskets.

31. Removal of Rocker Box Oil Drain Lines (fig. 15)

Loosen hose clamps on hose adapters at crankcase. Remove bolts holding lines to cylinders and pull lines and hose connections from crankcase. Discard gaskets.

32. Removal of Intake Manifolds

a. Detach hot-spot manifolds (figs. 1, 2, and 66) from intake manifolds and discard gaskets.

b. Remove nuts from mounting flanges and lift off intake manifolds. Discard gaskets.

33. Removal of Throttle Control

a. Detach control shaft center bearing housing (fig. 59) from engine lifting hook bracket.

b. Detach camshaft gear housing covers and lift entire throttle control assembly from engine.

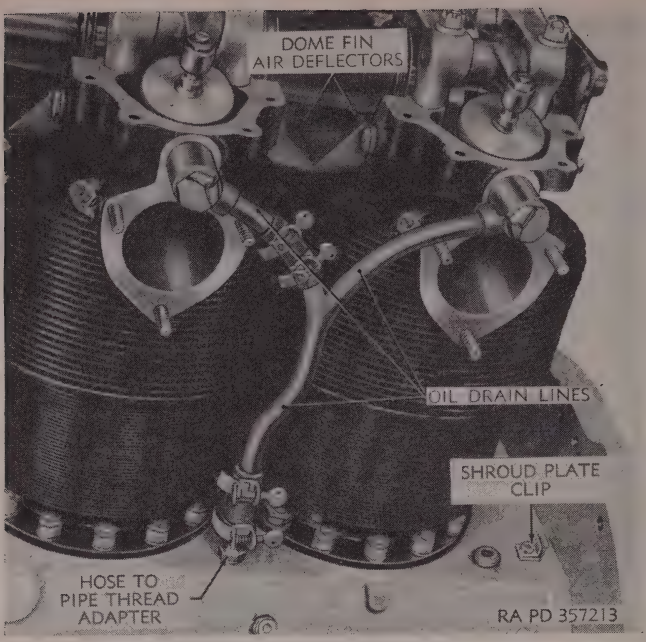
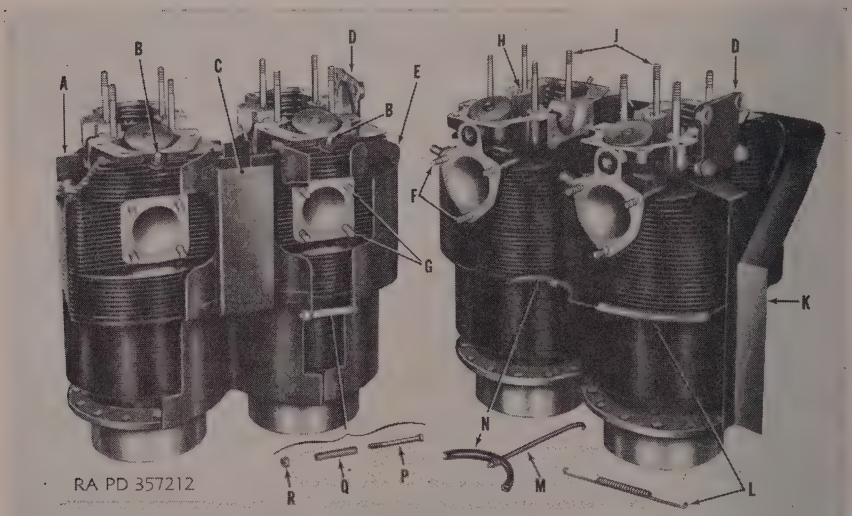


Figure 15. Rocker box oil drain lines.



A—DEFLECTOR, AIR—CO-302497, 8 LH, RH
B—STUD, SHROUD—CO-401823
C—DEFLECTOR, AIR—CO-515994
D—PLATE, ROCKER COVER—CO-515776
E—DEFLECTOR, AIR—CO-515999
F—STUD, INTAKE MANIFOLD—CO-401813
G—STUD, EXHAUST MANIFOLD—CO-401861
H—PIN, DOWEL—CO-501824
J—STUD, ROCKER BRACKETS—CO-401872
K—DEFLECTOR, AIR—CO-515998
L—SPRING, DEFLECTOR—CO-516038
M—HOOK, DEFLECTOR—CO-515997
N—CLAMP, DEFLECTOR—CO-302505
P—BOLT, DRILLED—AIR—AN4-25
Q—SPACER, DEFLECTOR—CO-302775
R—NUT, SLOTTED—AIR—AN355-4

Figure 16. Cylinder air deflectors.

34. Removal of Cylinder Air Deflectors (fig. 16)

a. Detach springs (L) holding end deflectors to deflector clamps (N). Remove bolts and spacers holding deflectors together. Lift off end deflectors No. 1 left and No. 6 right. Due to limited clearance at cylinder No. 1 right and No. 6 left, remove small dome fin air deflectors (fig. 15) from these deflectors to permit removal.

b. Loosen deflector clamp nuts, disengage hooks from intercylinder deflectors, and remove deflectors.

c. Remove air deflectors (A) from cylinders.

35. Removal of Valve Rocker Covers

The immediate covers are secured to the cylinder heads by eight bolts and can be lifted off after removal of the bolts (fig. 45). Covers on the No. 6 cylinders are bolted to end cover plates and No. 1 covers are bolted to camshaft bevel gear housings. Removal of these bolts, in addition to the eight head bolts, permit end covers to be removed.

36. Removal of Primer Lines (fig. 12)

Disconnect primer lines from accessory case and from cylinder connectors. Remove lines carefully without kinking and place them where they will be secure from damage.

37. Removal of Camshafts

a. Remove camshaft quill snap ring (fig. 41) from upper camshaft drive gear, using snap ring pliers (41–P–1992–36), and lift out oil transfer with remover and replacer (41–R–2378–575). With the same puller, remove the camshaft drive quill from housing (fig. 17).

b. Loosen valve rocker support bracket and camshaft bearing cap nuts a few turns at a time, until all are loose. Remove nuts and lift

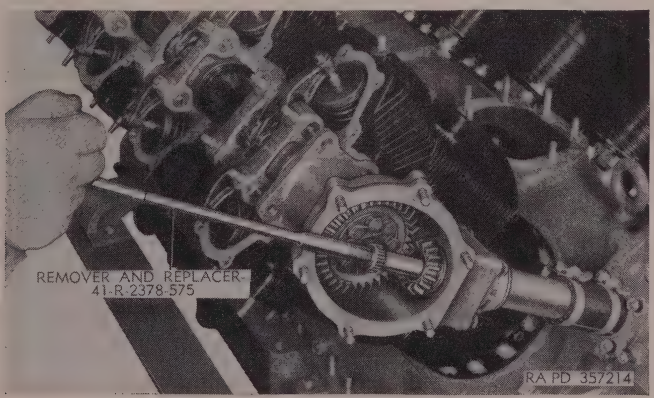


Figure 17. Removing camshaft drive quill.

off caps and brackets with valve rockers and shafts (fig. 45). These parts are marked with identifying numbers and must be installed in their original positions.

c. Remove two bolts holding camshaft gear housing (fig. 41) to cylinder. Loosen hose clamp nearest the accessory case and lift out camshaft and gear housing as a unit (fig. 18).

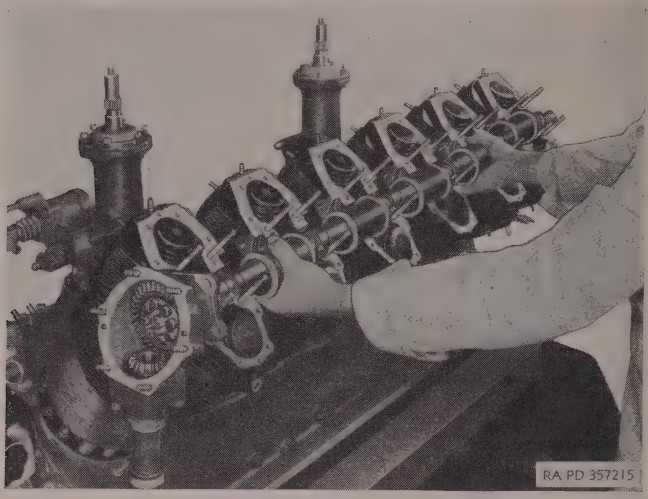


Figure 18. Removing camshaft and gear housing.

d. Install camshaft bearing caps and valve rocker support brackets in positions from which they were removed.

38. Removal of Oil Pan

Remove all nuts from the crankcase flange (fig. 52). Loosen nuts and cap screws holding oil pan at flywheel and accessory ends and jar oil pan loose with a soft hammer. It will be found more convenient to swing the engine stand, bring the oil pan to the top, and then lift it from crankcase. Remove oil sump screen and housing.

39. Removal of Accessory Case

a. Reverse engine stand to bring cylinders to the top. Remove covers (fig. 31) from accessory driven shaft support and power take-off drive, and discard gaskets.

b. With three pullers (41–P–2906–280), remove accessory driven shaft support (fig. 19).

c. Remove snap ring (fig. 31) from end of horizontal fan drive shaft with snap ring pliers (41–P–1992–35). Pull out the shaft with remover (41–R–2378–602) (fig. 20).

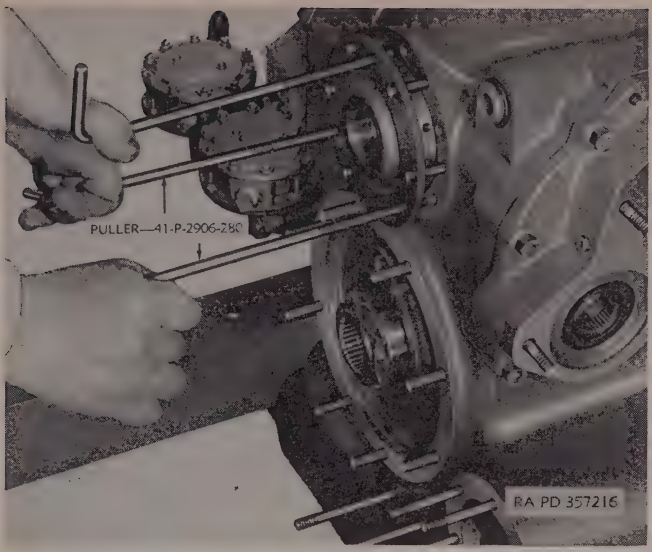


Figure 19. Removing accessory driven shaft support.

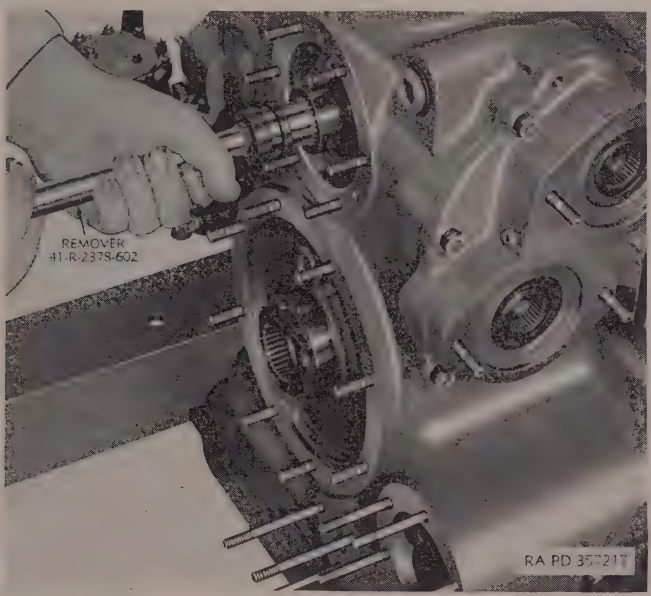


Figure 20. Removing horizontal fan drive shaft.

d. Remove internal snap ring from accessory drive gear shaft spline with snap ring pliers (41–P–1992–35). Pull accessory drive shaft with puller (41–P–2906–280) (fig. 21).

e. Remove nuts holding accessory case to crankcase. Free it from crankcase with a soft hammer, if necessary. Carefully lift it off the studs (fig. 22).

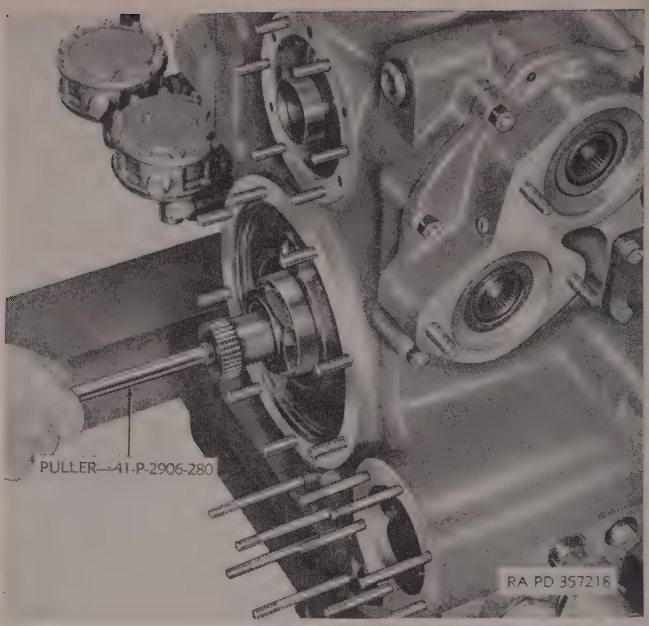


Figure 21. Removing accessory drive shaft.

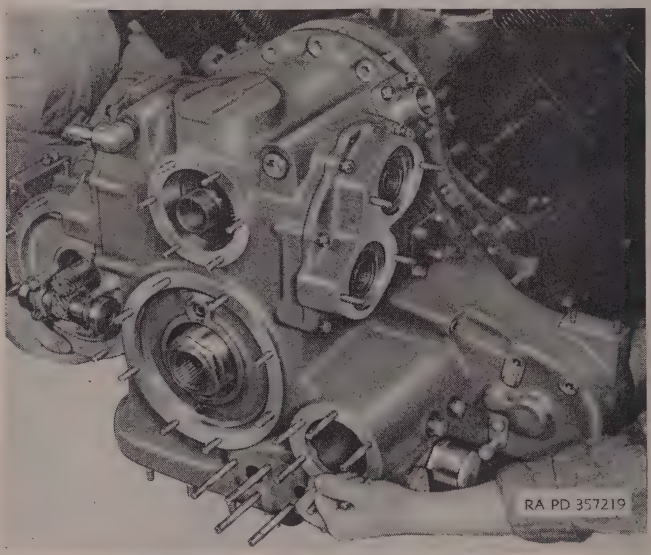


Figure 22. Removing accessory case.

40. Removal of Fan Drive Bevel Gear Supports

a. Reach through accessory end fan drive gear support and push fan drive shaft toward flywheel end, freeing it from the front fan drive bevel gear. Be careful not to pull the bevel gear from the support.

b. Insert pullers (41–P–2906–280) in the tapped holes, free support, and lift from crankcase (fig. 23).

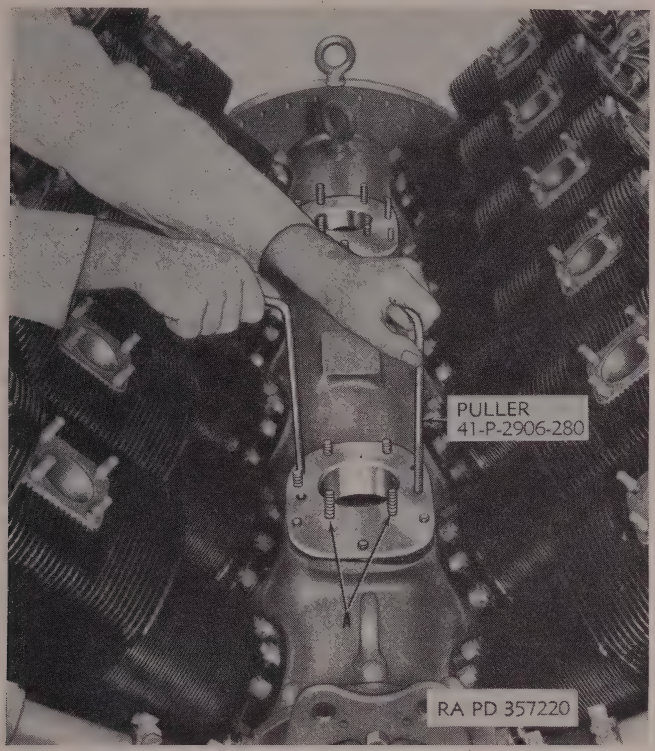


Figure 23. Removing fan drive bevel gear support.

c. Reach into crankcase through the flywheel end fan drive gear support and push gear and shaft toward accessory end until gear is seated in support. Reach into crankcase through support opening at accessory end and pass shaft out of crankcase through hole provided in end web.

d. Remove flywheel end support by proceeding as outlined in *b* above.

41. Removal of Cylinders

a. Remove lock nuts (fig. 45) from cylinder barrel hold-down nuts.

b. Check and record torque required to break loose each hold-down nut. With a torque wrench in combination with box wrench (41–W–872–715) for the large nuts, and box wrench (41–W–872–710) for the smaller nuts, note if torque required to break is less than 300 inch-pounds (fig. 24). If less, remove nut, apply mica base antiseize compound to stud, replace nut and tighten to torque of 350 inch-pounds. If nut does not tighten to this torque, the stud is stretching and must be marked for replacement.

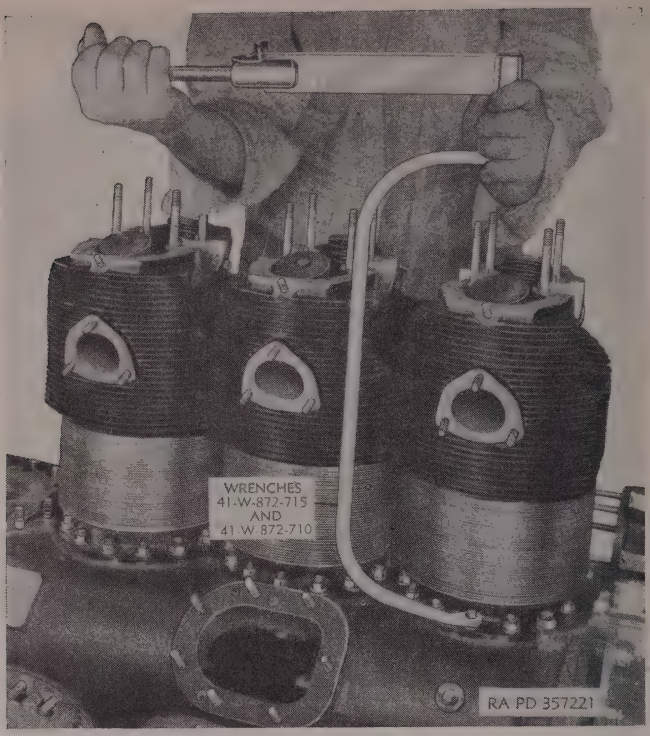


Figure 24. Torque reading of cylinder-barrel hold-down nuts.

c. Leave two opposite nuts on each cylinder to hold them in position. Remove all other nuts.

d. With engine turning wrench (41–W–906–125), bring piston in No. 1 cylinder (either side) to top center. This engine turning wrench is a tubular piece with external splines on one end, the opposite end pierced for a turning bar. The wrench can be inserted in the splines at the flywheel or into the splines of the crankshaft at accessory end.

e. Remove remaining two nuts holding cylinder, and loosen cylinder by jarring with hand. Pull cylinder straight out until it clears mounting studs.

Note. Before removing cylinder, place a connecting rod protector (41–P–2839–535) (fig. 25) on the rod to prevent possible damage to cylinder mounting pad; then remove the cylinder.

f. Support piston and push out piston pin. If carbon deposit makes it difficult to remove, tap with a wooden pin.

Note. Pistons in the No. 1 and No. 6 cylinders will be at top center together, and both cylinders can be removed without turning engine. Piston No. 2 and No 5, and No. 3 and No. 4 operate together.

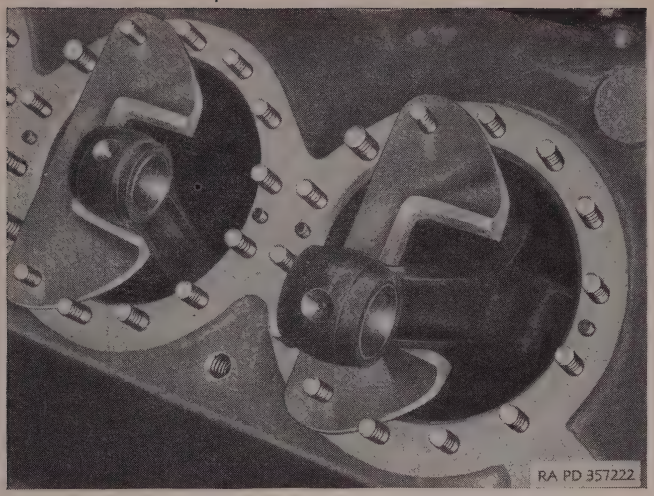


Figure 25. Connecting rod protector (41–P–2839–535).

42. Removal of Flywheel, Torsion Damper, and Transmission Adapter (fig. 26)

a. Remove 12 self-locking socket head bolts holding flywheel cover plate (C) to flywheel. This plate usually can be removed by tapping around its edges with a soft hammer. Tapped holes are provided for pusher bolts if it is difficult to remove. Torsion damper spring (F) will pull out with cover plate.

b. Remove damper pressure plate (G) and friction disc (H).

c. Lift out spring driven plate (J) with gears attached. To remove gears remove external ring (A) with pliers (41–P–1992–49) and slip the transmission oil pump drive gear (B) off splines. Remove four bolts from input shaft accessory drive gear (D) and press it off dowel pins. Remove the friction disc (H), spacer plate (L), and drive spring and seat assemblies (P and Q) from flywheel.

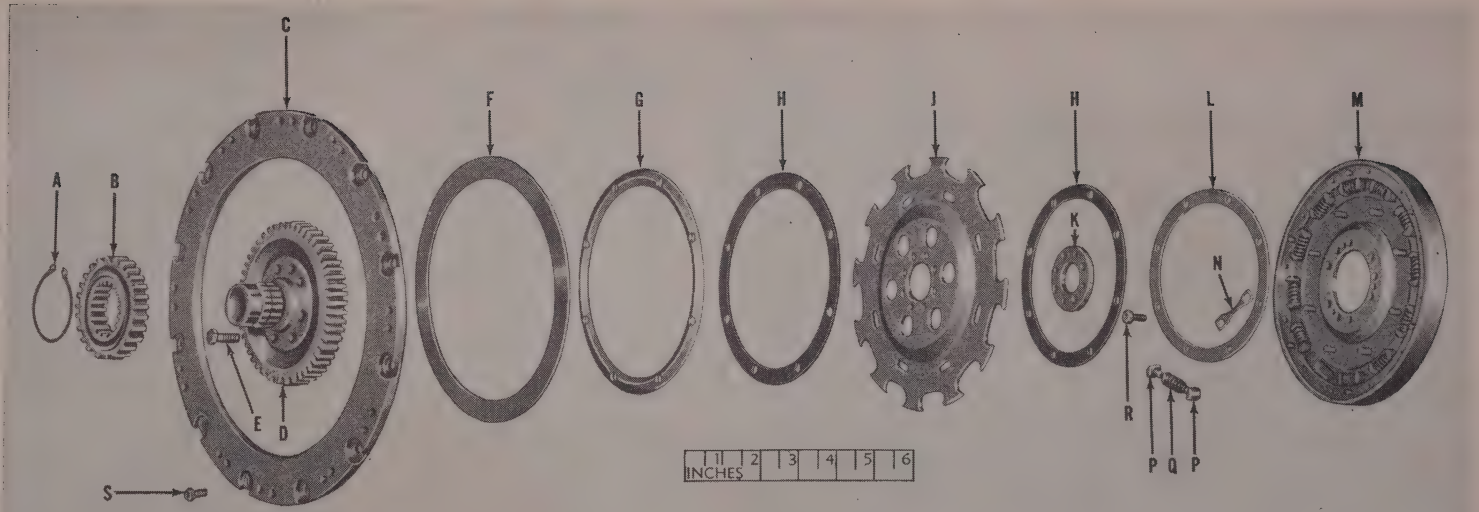
d. Disengage flywheel bolt locks (N) and remove flywheel bolts from crankshaft hub. Remove flywheel from crankshaft with pusher bolts.

e. Remove slotted nuts holding transmission case adapter (fig. 52) to crankcase and remove adapter.

43. Removal of Crankshaft Vibration Damper Counterweights

a. The crankshaft vibration damper hub is assembled permanently and is *not* removable from the crankshaft, nor should the hub bolts be disturbed.

b. Remove four bolts and lift out counterweight stop plate. Support counterweights and remove pins (fig. 54). These counterweights are matched sets. Both counterweights and pins are marked,



A—RING, RETAINING—CO-502571
B—GEAR, TRANSMISSION OIL PUMP DRIVE—CO-515337
C—PLATE, FLYWHEEL COVER—CO-515428
D—GEAR, INPUT SHAFT ACCESSORY DRIVE—CO-515425
E—BOLT, DRILLED HEX HEAD—AIR—AN8H-16
F—SPRING, TORSION DAMPER—CO-514800
G—PLATE, PRESSURE—CO-514799
H—DISC, FRICTION—CO-514907
J—PLATE, SPRING DRIVEN—CO-515426
K—PLATE, HUB—CO-514796
L—PLATE, SPACER—CO-514793
M—FLYWHEEL—CO-516747
N—LOCK, FLYWHEEL BOLT—CO-302784
P—SEAT, DRIVE SPRING—CO-514798
Q—SPRING, DRIVE—CO-514797
R—BOLT, DRILLED HEAD—CO-401374
S—BOLT, HEX HEAD—CO-502474

RA PD 357223

Figure 26. Flywheel and Torsion Damper—exploded view.

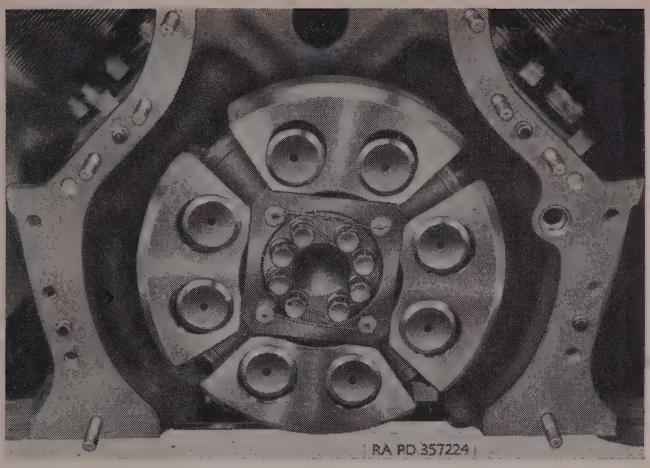


Figure 27. Crankshaft Vibration Damper.

showing original positions, and the group should be kept with its original crankshaft.

44. Removal of Crankshaft (fig. 52)

a. Remove cotter pins from cross bolt nuts (G) on one side of crankcase. With an assistant holding opposite ends from turning, back off cross bolt nuts evenly until all are loose.

b. Turn engine stand and bring open side of crankcase up. Detach and remove oil inlet lines (M and N) and inlet line bracket (L) at accessory end; small bracket (CC) on oil seal housing need not be removed.

c. Remove loosened cross bolt nuts and withdraw bolts (G). Support cross bolt spacers (Y) as bolts are removed, and remove spacers.

d. Remove oil seal retaining plates (PP) from oil seal housing. Remove the nuts and two flathead machine screws holding the housing assembly to crankcase. Remove the nuts (TT) holding upper and lower housings together and remove the housings. Unhook the ends of the oil seal spring and remove the split oil seal (LL) from the crankshaft.

e. Remove locking wires and loosen all main bearing cap nuts (Z). Note that these cap nuts have a slightly spherical face and seat in special cup-shaped washers. This feature is to prevent eccentric loading of main bearing studs when they are stressed to require torque. Remove nuts and identify them so they can be installed on studs from which they were removed. These nuts were selected at original assembly so that a slot would register with drilled hole in stud when pulled up to the specified torque.

f. Install main bearing cap puller (41–P–2942–200) (fig. 28). Run wing nut back and screw end of puller screw into tapped hole in bear-

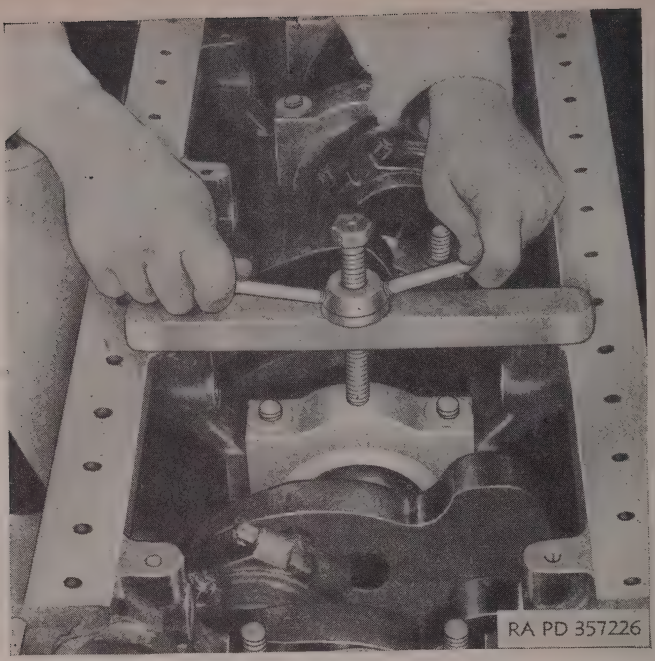


Figure 28. Removing main bearing caps with puller (41–P–2942–200).

ing cap. Turn wing nut down until bearing cap is free. Be careful that bearings do not drop out of bearing caps. They are damaged easily.

Note. Main bearing caps are stamped, identifying their original positions, and are not interchangeable. Main bearings are etched at installation. When removing bearings, observe if original marking, on the back, is legible. If it is not, renew the marking with a grease pencil. Never mark a bearing with a metal instrument.

g. Hook crankshaft lifting sling (7082025) to the center counterweights and lift crankshaft with chain fall (fig. 29). Remove connecting rod protectors (fig. 25), lift shaft slowly, and guide it. Be careful not to injure bearing cap studs. Place crankshaft on "V" blocks placed under the end journals.

Section IV. REBUILD OF ACCESSORY CASE

45. Disassembly of Accessory Case (fig. 31)

a. General. The disassembly steps given are in a practical order but the sequence given is not mandatory and may be altered to suit convenience. Figure 30 shows the accessory case assembled. The exploded view (fig. 31) shows the bushings removed from the housing *for identification purposes only.* It must be understood that bush-

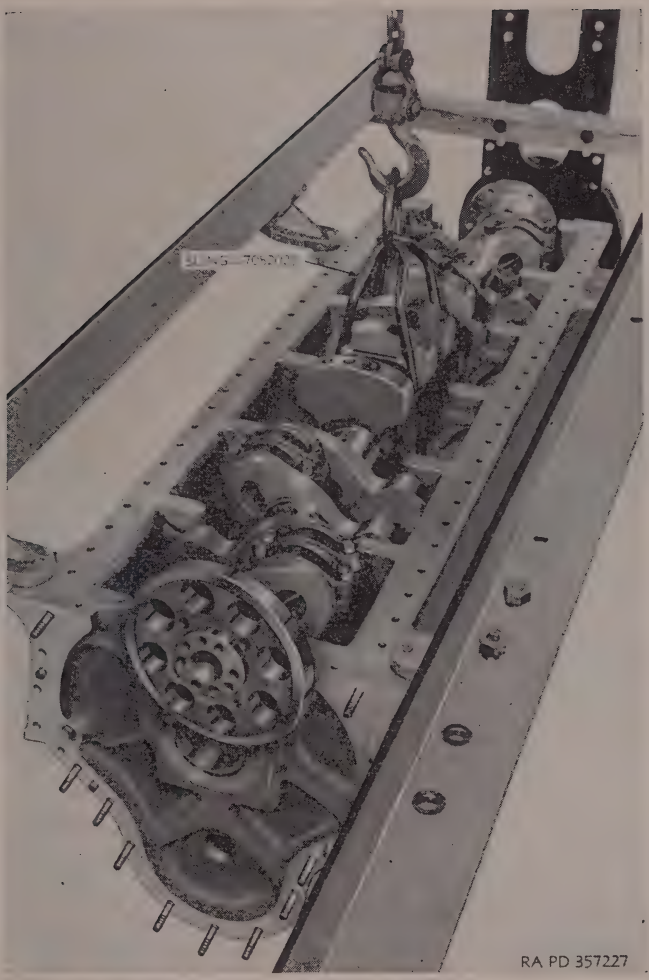


Figure 29. Lifting crankshaft.

ings are *not* removed in general disassembly. Their removal and replacement, as necessary, are covered in paragraph 46*c*.

b. Remove Oil Pump. The oil pump is mounted on the bottom of accessory case (fig. 30). Remove nuts from mounting flange and pull oil pump assembly off studs. This assembly is a very important unit. It is manufactured with extreme precision and is not to be repaired. Inspect the unit without prior disassembly. See serviceability standards, paragraph 134.

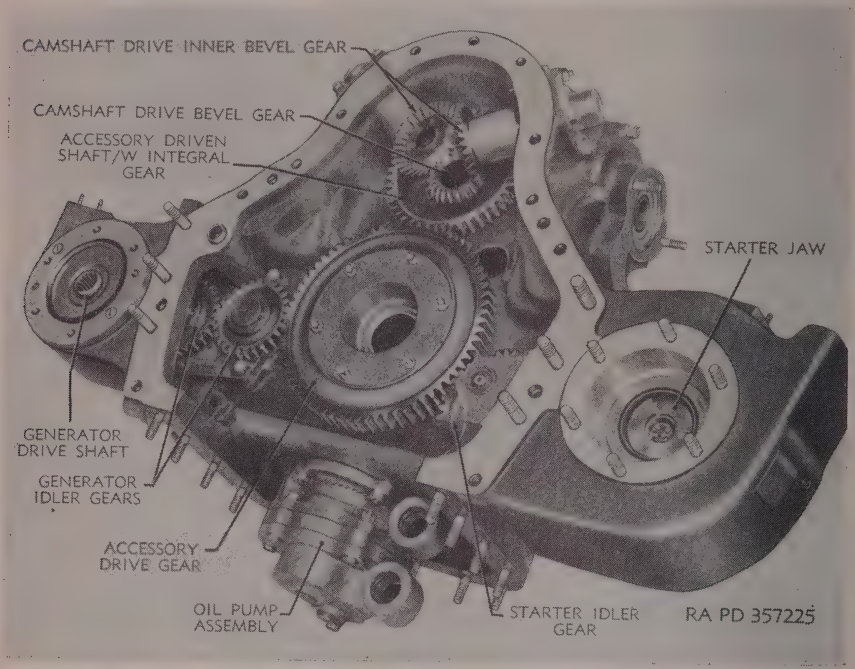


Figure 30. Accessory case assembled.

c. Remove Generator Adapter. This adapter is installed with a close fit in the accessory case. Two tapped holes are provided for pullers (41–P–2906–280) (fig. 32). The generator drive shaft will pull out with adapter.

d. Remove Fuel Pump Drive Shaft Adapter Assembly (fig. 39).

(1) With pullers (41–P–2906–280), pull adapter assembly from its studs (fig. 33).

(2) Remove fuel pump driven gear bearing caps and lift gear from bearings.

e. Remove Starter Drive Gear Assembly (fig. 39). Separate starter drive gear and jaw assembly from fuel pump drive shaft adapter and disassemble.

(1) Remove starter drive gear hub (G) from starter drive gear (H).

(2) Remove cotter pin and castellated nut from center of starter jaw (J) and remove jaw from drive gear hub.

(3) The fuel pump drive gear (E) is pinned through an extension on starter hub and may be removed by driving out pin (F).

f. Remove Magneto Adapters (figs. 37 and 38).

(1) Remove flange mounting nuts holding magneto adapters to case, and pull assemblies off studs. Be careful not to drop magneto advance units. Discard gaskets.

(2) Disassemble the magneto adapters by lifting out the ignition drive shafts, the advance unit assemblies, and all gears. Remove the tachometer drive cover (Q) (fig. 37) and discard gasket. Remove oil seals from both adapters.

g. Remove Camshaft Drive Inner Supports (fig. 41).

(1) Remove nuts holding supports (Q) to accessory case.

(2) Support inner bevel gears (M), pull supports from case, and remove gears. Remove inner oil transfer plugs (N) from gears.

h. Remove Accessory Driven Shaft (fig. 31). Pull accessory driven shaft (T) from case, lift ignition drive bevel gears from case, and remove camshaft drive bevel gear (V) from splines in shaft.

i. Remove Main Accessory Drive Gear and Shaft (fig. 31).

(1) Disengage accessory drive gear shaft nut lock (AF), remove hex shaft nut (YY), and slip off power take-off gear replacement sleeve (AG).

(2) Pull accessory drive gear (CC) and shaft (X) from case. Be careful not to drop oil pump drive bevel gear (Y) which engages splines near center of shaft.

(3) The gear and shaft can be separated by removing bolts from shaft flange and gear web.

j. Remove Generator Idler Gears and Idler Gear Bracket (fig. 31).

(1) Remove snap rings (FF) and thrust washers (GG) from idler gear stub shafts on idler gear bracket (TT), and remove gears.

(2) Disengage tab washers and remove bolts holding idler gear bracket to case.

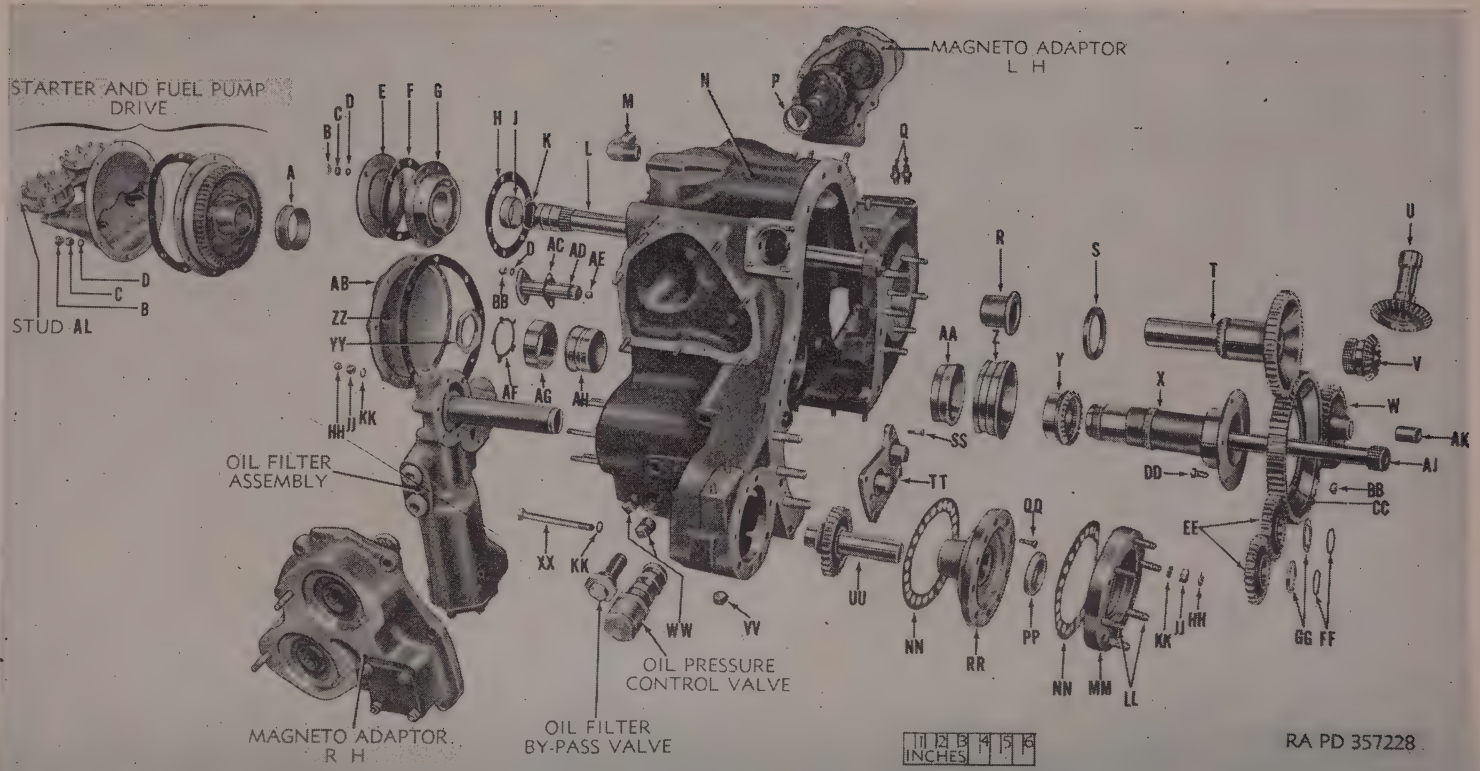


Figure 31. Accessory case—exploded view.

A—BEARING, STARTER DRIVE GEAR HUB—CO–301748
B—NUT, LOCK—AIR–356–524
C—NUT, PLAIN—AIR–AN360–5
D—WASHER, PLAIN—AIR–AN960–516
E—COVER, ACCESSORY DRIVEN SHAFT SUPPORT—CO–301738
F—GASKET, SUPPORT COVER—CO–301753
G—SUPPORT, ACCESSORY DRIVEN SHAFT—CO–301739
H—GASKET, ACCESSORY DRIVEN SHAFT SUPPORT—CO–301753
J—BEARING, ACCESSORY DRIVEN SHAFT SUPPORT—CO–301740
K—RING, SNAP—CO–502020
L—SHAFT, FAN-DRIVE, HORIZONTAL, ASSY—CO–515491
M—ELBOW—AIR–AN842–12
N—CASE, ACCESSORY—CO–515447
P—BEARING, IGNITION DRIVE DRIVEN BEVEL GEAR—CO–301745
Q—CONNECTOR, UNION—AIR–AN780–2
R—BEARING, ACCESSORY DRIVEN SHAFT—CO–301747
S—SEAL, OIL, STARTER GEAR HUB—CO–502021
T—SHAFT, ACCESSORY, DRIVEN—CO–515514
U—GEAR, BEVEL, CAMSHAFT DRIVE INNER—CO–515481
V—GEAR, BEVEL, CAMSHAFT DRIVE—CO–515482
W—GEAR, STARTER IDLER—CO–516749
X—SHAFT, ACCESSORY DRIVE GEAR—CO–515905
Y—GEAR, BEVEL, OIL PUMP DRIVE—CO–515506
Z—BEARING, ACCESSORY DRIVE SHAFT, (REAR)—CO–301755
AA—BEARING, OIL PUMP DRIVE BEVEL GEAR—CO–302535
BB—NUT, SLOTTED—AIR–AN355–5
CC—GEAR, ACCESSORY DRIVE—CO–301681
DD—BOLT, HEX-HEAD—CO–401367
EE—GEAR, GENERATOR DRIVE IDLER—CO–302312
FF—RING, SNAP—CO–502025
GG—WASHER, THRUST—CO–301789
HH—NUT, LOCK—AIR–356–624
JJ—NUT, PLAIN—AIR–AN360–6
KK—WASHER, PLAIN—AIR–AN960–616
LL—STUD, GENERATOR MOUNTING—CO–502468
MM—PLATE, GENERATOR MOUNTING—CO–516022
NN—GASKET, GENERATOR—CO–302341
PP—SEAL, OIL—CO–502104
QQ—SCREW, MACHINE, FLAT-HEAD—AIR–AN505–416–14
RR—ADAPTER, GENERATOR DRIVE SHAFT—CO–515480
SS—BOLT, HEX-HEAD—AIR–AN5–7A
TT—BRACKET, GENERATOR DRIVE IDLER GEAR—CO–515542
UU—SHAFT, GENERATOR DRIVE—CO–515486
VV—PLUG, PIPE—CO–401749
WW—PLUG, PIPE—CO–401756
XX—BOLT, DRILLED HEAD—AIR–AN6H–47
YY—NUT, ACCESSORY DRIVE GEAR SHAFT—CO–515942
ZZ—GASKET, DRIVE COVER—CO–515943
AB—COVER, POWER TAKE-OFF DRIVE—CO–515944
AC—GASKET, STARTER IDLER GEAR SHAFT—CO–301097
AD—SHAFT, STARTER IDLER GEAR—CO–516738
AE—PLUG, PIPE—CO–401752
AF — LOCK, ACCESSORY DRIVE GEAR SHAFT NUT—CO–515946
AG—SLEEVE, REPLACEMENT POWER TAKE-OFF GEAR—CO–515941
AH—BEARING, ACCESSORY DRIVE SHAFT, FRONT—CO–301756
AJ—SHAFT, ACCESSORY DRIVE—CO–517381
AK—BEARING, STARTER IDLER GEAR—CO–516740

Figure 31—Continued.

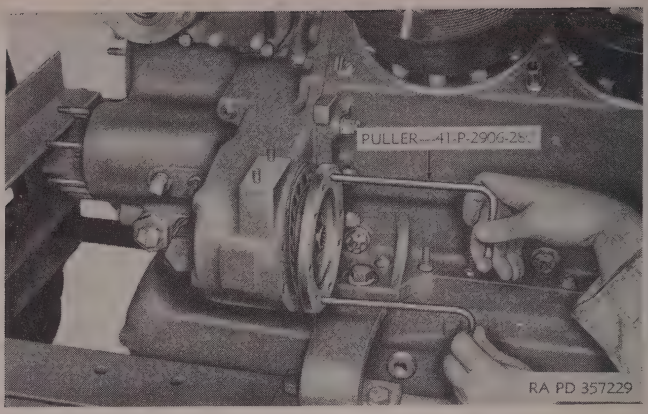


Figure 32. Removing generator adapter.

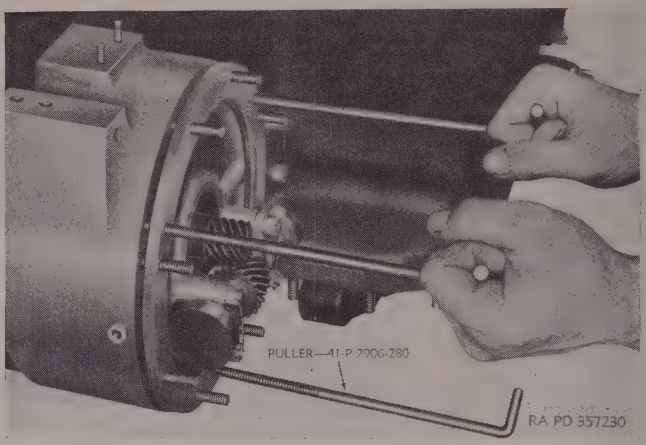


Figure 33. Removing fuel pump drive shaft adapter assembly.

k. Remove Starter Idler Gear (fig. 31). The starter idler gear shaft (AD) is inserted from the front of accessory case, passed through gear (W) and into supporting bearing. Remove bolts from shaft flange, support the gear, and pull shaft from case. Discard gasket.

l. Remove Oil Filter By-Pass Valve (fig. 34).

(1) This valve is the smaller of two valves mounted in the lower right side of the case. Using wrench (41–W–3727–33), remove valve assembly from case.

(2) To disassemble valve, remove hex-head cap from housing (fig. 64). Compress assembly until cotter pin can be removed from valve stem, then disassemble. Discard annular gaskets.

m. Remove Oil Pressure Control Valve (fig. 34).

(1) With wrench (41–W–3727–33), remove valve assembly from accessory case.

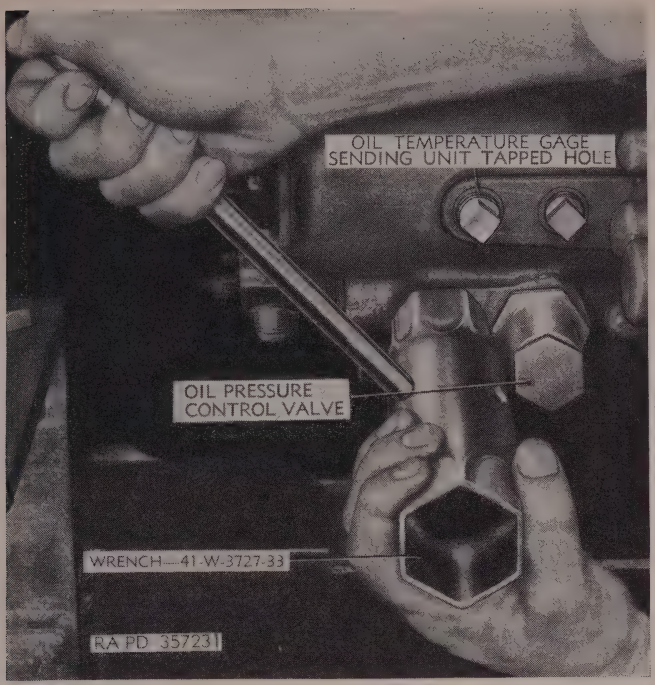


Figure 34. Removing oil-pressure control valve and oil-filter by-pass valve.

(2) To disassemble, remove hex-head cap from valve housing (fig. 63). Lift out spring and spring seat. Remove valve seat from housing and remove valve. Discard annular gaskets.

46. Cleaning, Inspection, and Repair of Accessory Case

a. Cleaning. The importance of cleaning must be understood thoroughly by ordnance maintenance personnel. Scrupulous care and conscientious effort are required in all cleaning operations. The presence of dirt or foreign substances is a constant threat to satisfactory engine operation. All parts must be cleaned before inspection, after repair, and before reassembly. Protect all parts from accumulation of dust and grit after cleaning. The inner and outer surfaces of all castings and all parts subject to oil lubrication must be cleaned with dry-cleaning solvent or volatile mineral spirits paint thinner. Pay particular attention to all oil passages in both castings and machined parts. When necessary, wire or probes must be used to break up all sludge or gum deposits and admit the cleaning solvent. Passages must be blown out with compressed air to free them from all foreign particles.

b. Inspection.

(1) *Castings.*

(*a*) Check the casting carefully for cracks, paying particular attention to areas adjacent to studs. Replace castings showing such evidence.

(*b*) Examine all mating surfaces for nicks or deep scratches and remove all burs or raised metal with a fine mill file.

(*c*) Watch for local discolorations on mating flanges as they often indicate persistent leaks. Test all such flanges with a straightedge or on a surface plate. Parts with warped flanges or mounting pads should be replaced.

(2) *Studs.*

(*a*) *Damaged studs.* Inspect all studs for damaged threads. Minor damage may be corrected with a standard thread chaser. Studs with stripped threads, bent or loose studs, or studs showing any evidence of stretch must be replaced.

(*b*) *Removing studs.* Back studs out slowly to avoid heating and possible seizure. Broken studs too short to be removed with a wrench may be drilled and extracted with an "easy out." If it is impossible to remove them by this method, a piece of bar stock or a nut may be welded to the stud. This method must be used with care to avoid damage to housing.

(*c*) *Replacing studs.*

1. Clean out tapped holes. Use an old tap because a new tap may cut oversize. If the tap appears to be cutting metal, try another tap. Inspect the threads. If there is any indication of stripped or damaged threads, or if the stud was removed because of looseness, the hole must be retapped to the next larger oversize.

2. Oversize studs are supplied for replacement (table II). Studs are marked on the housing end to indicate whether they are standard or oversize. Check the marking to be sure the replacement is of the proper size. Be sure the correct end is threaded into the housing. As a further check, note that the stud threads are of different size, the coarser thread being the housing end.

3. A small amount of mica base antiseize compound should be applied to the threads before installing studs. Drive studs in slowly to prevent heating. Observe the setting height as given on stud chart (table II).

4. When, from any cause, the tapped holes in castings are damaged beyond salvage by oversize studs, they will be fitted with helicoil inserts and new studs of the original size installed. For the method of installation of these

helicoil inserts and their removal, see the pertinent operator's manual.

(3) *Gears.* Inspect all gears visually for sharp fins or burs at tooth corners and for galling or pitting on the tooth faces. Replace all gears showing such defects. If magnaflux testing equipment is available, check all gears by this method and replace those in which cracks are evident. Check all gears to the limits specified in serviceability standards (pars. 117, 120, and 128–130). Inspect the bearings in the magneto drive gears and the starter idler gear. If not serviceable, use satisfactory gear assemblies. See that the cup plug is secure in the generator drive shaft. It is not necessary to disassemble the starter and fuel pump drive assembly unless inspection reveals damage. If necessary, it may be disassembled as follows (fig. 39) :

(*a*) Remove cotter pin and nut holding starter jaw in position.

(*b*) Drive out pin that fastens the drive gear to the hub.

(*c*) Remove gear from hub.

(4) *Splines.* Check all splines for fit with the mating part; they must enter freely and move easily. Stone off any slight rough spots or burs and polish with crocus cloth.

(5) *Shafts.* Check shafts by magnaflux. If this equipment is not available, inspect all shafts with a magnifying glass for cracks. If cracks are discovered, the shaft must be scrapped. Raised metal at nicks or scratches should be stoned off and polished with crocus cloth. Check dimensions specified in serviceability standards (pars. 117, 122, 126, 128, 130, and 137).

(6) *Bushing-type bearings.* Check all bearings carefully for looseness in housing and for evidence of heating. Heating is an indication of insufficient lubrication; examine the oil passages in the case and be sure they are clean. Loose or damaged bearings must be replaced (*c* below).

(7) *Oil passages and oil plugs.* See that the oil passages in the generator idler gear bracket (TT) (fig. 31), camshaft oil transfer plugs (DD) (fig. 41), and starter idler gear shaft (AD) (fig. 31), are clean. Be sure that oil passage plug in bracket and plug in the shaft are secure. Check oil transfer plugs to serviceability standards (par. 120).

(8) *Adapter and cover plates.* Inspect all accessory adapter and cover plate castings (*b*) (1) and (2) above). Check for loose or damaged adapter bearings. Replace adapter assembly when either bearing or adapter is damaged. All bearing areas should have any raised metal resulting from nicks or scratches removed with a fine mill file.

c. Repair.

(1) All bushing-type bearings are replaceable and complete fixture sets are provided for finish reaming when a new bearing is installed (figs. 5 and 35).

(2) All bearings are pinned in place. Drill jigs are used to install the pins and the same jigs are used for their removal. To remove a bearing, prick-punch the pin ends and aline

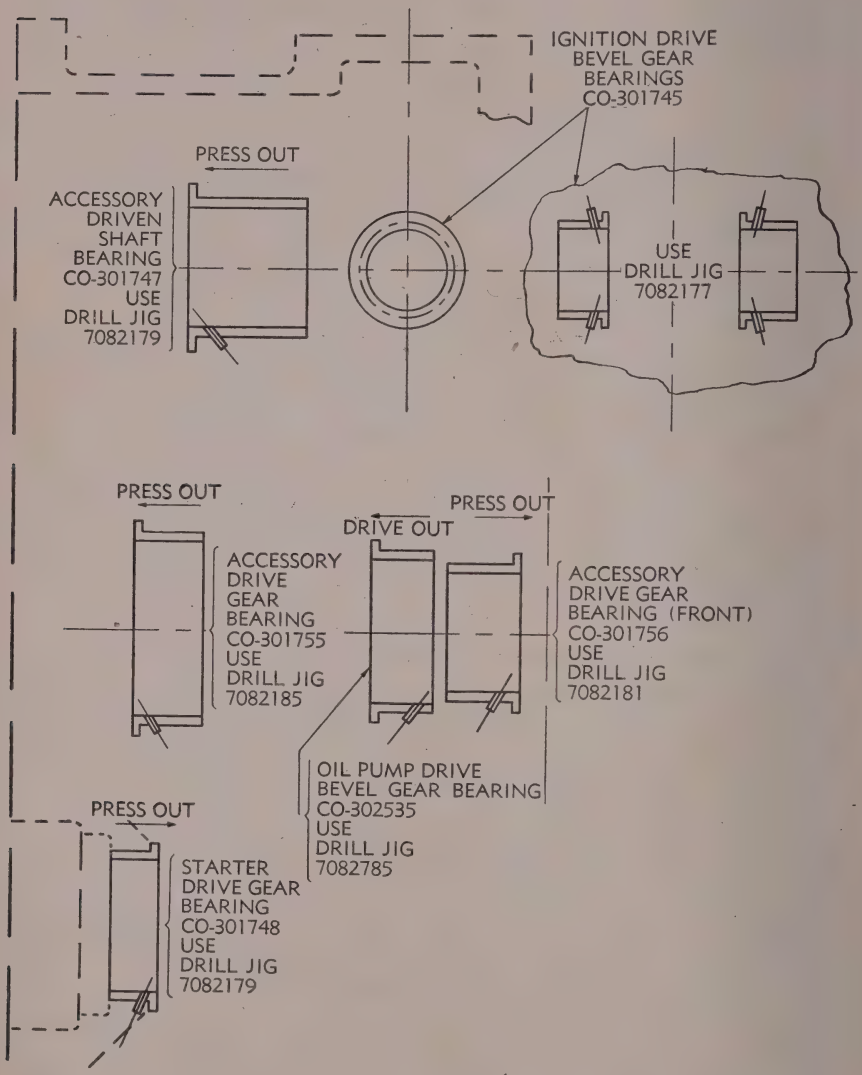


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Figure 35. Diagram of accessory case bushings.

the jig. Drill out the pins, using a portable drill with an angle chuck. It is necessary to drill through the bearing only, not the entire pin length. Figure 35 indicates the various bearings, the general location of the pins, and the drill jig to be used in removal. Press out bearings after pin removal.

(3) To remove the oil pump drive bevel gear bearing (AA) (fig. 31) after drilling out pins, use remover (41–R–2369–535) (QQ) (fig. 4). Place the halves of the split remover together; insert them in bore so that the thin flanges are back of the bearing. Turn bolt into threaded halves from front of case and drive out bearing toward crankcase side.

(4) As an alternative to the removal procedure described in (2) and (3) above, the bearings may be bored out to a thin shell which can be collapsed and removed. The projecting pins then may be ground off.

(5) Mark the position of the original pins so that the marks can be seen after the replacement bearing is in place. Replacer (41–R–2388–715) for the starter drive gear hub bearing (A) (fig. 31), and replacer (7082786) for the oil pump drive bevel gear bearing are provided to drive these bearings into place. The other bearings may be pressed into place.

(6) Install appropriate drill jig (fig. 35) so that pin holes will be in new metal. Use a portable drill with an angle chuck and a No. 31 drill. The pin holes are drilled 0.50 inch deep for the accessory driven shaft bearing (R) (fig. 31). All other pin holes are drilled 0.38 inch deep.

(7) The accessory driven shaft bearings and three accessory drive shaft bearings are reamed and spot-faced with tools provided in fixture set (7082775) (fig. 36).

(8) To ream and spot-face accessory driven shaft bearing, proceed as follows:

(*a*) Place fixture assembly (7082776) (G) on the open side of accessory case, locate dowels, and secure to the studs.

(*b*) Assemble reamer (7082288) (F) on reamer arbor (7082284) (D). Insert assembly in fixture and ream bearing.

(*c*) To spot-face bearing replace reamer (7082288) (F) with cutter (7082289) (E), and cut bearing flange until collar on reamer assembly contacts fixture.

(9) To ream and spot-face the three bearings on the accessory drive gear shaft, proceed as follows:

(*a*) With fixture assembly (7082776) (G) in place, as described in (8) (*a*) above, locate and secure fixture assembly

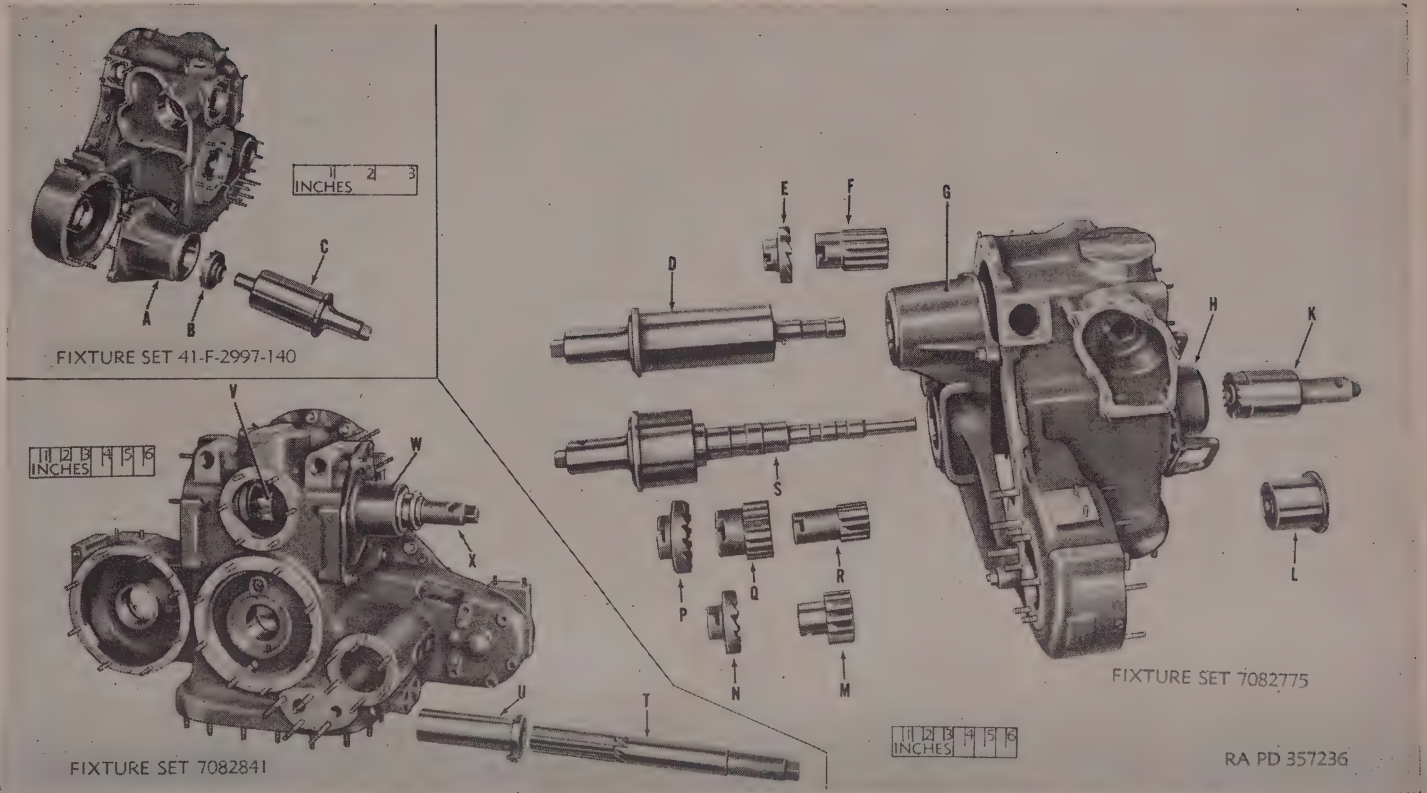


Figure 36. Application of reaming fixtures to accessory case.

A—FIXTURE—7082244
B—CUTTER, SPOT-FACING—7082254
C—ARBOR, REAMER—7082251
D—ARBOR, REAMER—7082284
E—CUTTER, SPOT-FACING—7082289
F—REAMER—7082288
G—FIXTURE ASSY—7082776
H—FIXTURE ASSY—7082779
K—REAMER ASSY—7082298
L—BUSHING, FIXTURE PILOT—7082277
M—REAMER—7082295
N—CUTTER, SPOT-FACING—7082294
P—CUTTER, SPOT-FACING—7082297
Q—REAMER—7082296
R—REAMER—7082293
S—ARBOR, REAMER—7082291
T—REAMER—7082238
U—BUSHING, FIXTURE PILOT—7082234
V—CUTTER, SPOT-FACING—7082177
W—FIXTURE—7082842
X—ARBOR, REAMER—7082845

Figure 36.—Continued.

(7082779) (H) to the front of accessory case, and insert and secure the pilot bushing (7082277) (L).

(*b*) To ream and spot-face front accessory drive gear bearing, assemble reamer (7082293) (R) on reamer arbor (7082291) (S). Insert assembly, guiding pilot into fixture bearing (L), and ream bearing. Withdraw reamer assembly, remove reamer, and replace reamer arbor. Lock it in place in fixture with swivel clamp. Remove pilot bushing from fixture (H) on front of case. Insert reamer assembly (7082298) (K) and spot-face bearing until collar contacts fixture.

(*c*) To ream and spot-face oil pump drive bevel gear bearing and accessory drive gear bearings, install fixture pilot bushing (7082277) (L) in front fixture. Use reamer (7082295) (M) and cutter (7082294) (N) with reamer arbor (7082291) (S).

(*d*) To ream and spot-face accessory drive gear bearing, use reamer (7082296) (Q) and cutter (7082297) (P) on reamer arbor (7082291) (S).

(10) Fixture set (7082841) (fig. 36) is provided for reaming and spot-facing the two ignition drive gear bearings. Locate and secure fixture assembly (7082842) (W) on magneto adapter studs on right side of accessory case. With reamer fixture pilot bushing (U) in fixture, line-ream both bearings with reamer (7082238) (T). Remove reamer and reamer bushing. Insert reamer arbor (7082845) (X) partially in fixture. The spot-facing cutter (V) is installed on reamer assembly through front opening in case. Face bearing until reamer assembly collar seats on fixture. Remove cutter and reamer assembly. Remove fixture and attach it to left side of case. Spot-face right-hand bearing.

(11) Fixture set (41–F–2997–140) (fig. 36) is used for starter drive gear hub bearing. Secure fixture (7082244) (A) to starter mounting studs, and ream with reamer arbor (7082251) (C) and reamer (7082253). Spot-face with cutter (7082254) (B).

47. Assembly of Accessory Case (fig. 31)

a. General. The engine is a precision product; consequently, the serviceability standards of its component parts have been fixed at extremely close limits. Extreme care must be exercised in all phases of the reassembly operation to insure satisfactory engine performance. A few general rules for reassembly follow.

(1) Cleanliness is essential in all assembly operations. Dirt and dust, even in minute quantities, are abrasive. Protect the

assemblies from wind-blown dust. Be sure that the parts have been cleaned as specified; be sure they are kept clean. Hands must be kept free from an accumulation of grease which collects dust and grit. Clothing which is impregnated with dust and grime will not be worn during assembly operations.

(2) Coat all bearings, shafts, and contact surfaces before assembly with the engine oil appropriate for the atmospheric temperature ranges. This is to assure adequate lubrication of the parts until pressure lubrication reaches them.

(3) Always use new gaskets on joints which confine oil. Annular copper asbestos gaskets never will be reused after their removal. Generally "O" ring gaskets will not be reinstalled, although some may be serviceable. If reinstalled, they should be examined carefully for deformation, hardening, or cracks. Metal-cased oil seals, such as are used in the magneto adapters, the generator adapter, or the starter mounting, normally are long-life parts and may be reused, if in good condition. The contact material, either leather or synthetic, must be pliable and show no evidence of burning. Note also that in this type of sail, a thin, featheredge contacts the rotating part. If this thin edge is destroyed, the seal is worthless.

(4) Always use plain washers under nuts on aluminum surfaces.

(5) Be especially careful to see that all bolts and nuts are secured with lock nuts, tab washers, locking wires, or cotter pins, as may be specified. A large proportion of engine failures have been traced to the neglect of this simple precaution.

b. Assembly (fig. 31).

(1) Install the engine oil temperature gage sending unit in the location indicated in figure 34. Install pipe plugs in the remaining oil passage openings. Install a ⅛-inch pipe plug in the primer inlet.

(2) Lubricate all bearings and gear supports with engine oil.

(3) Install generator drive idler gear bracket (TT) with four bolts that are secured by tab washers. Two of the bolts are installed from inside and two from the outside of the accessory case. Put generator drive idler gears (EE) over bracket bosses, install a thrust washer (GG) over each boss and, using pliers (41–P–1992–28), install snap ring (FF) in the slot provided in each boss.

(4) Install generator drive shaft (UU) and shaft adapter (RR), using a new gasket between adapter and accessory case. Two flathead machine screws (QQ) hold adapter in position. Install generator drive shaft oil seal (PP).

(5) Install new gasket (AC) over starter idler gear shaft. While

holding starter idler gear (W) in position, insert shaft into bore at front of accessory case, and push it through idler gear and into boss at rear of case. Secure the shaft flange with plain washers, slotted nuts, and locking wire.

(6) If accessory drive gear (CC) has been separated from gear shaft (X), install it with 12 bolts, slotted nuts, and locking wire. Insert oil pump drive bevel gear (Y) in its bearing. Install drive gear assembly. Slip power take-off gear replacement sleeve (AG) over gear shaft splines. Install tab-type nut lock (AF). Run gear shaft nut into position. Lock by bending tabs over nut flats.

(7) Install accessory driven shaft support (G), using new gasket between support and accessory case. Insert ignition drive driven bevel gears in their bearings from inside the case. Install accessory driven shaft (T).

(8) Insert camshaft drive bevel gear (V) in its mating splines in accessory driven shaft (T). To install camshaft drive inner bevel gears (U), hold gears in position on inner side of accessory case and insert camshaft drive inner supports ((Q fig. 41) into accessory case and over the hubs of gears. Use new "O" ring gaskets on inner supports. Secure supports with plain washers, plain nuts, and lock nuts. Install the camshaft drive inner oil transfer plugs in bevel gears (U).

(9) Check automatic ignition advance units (figs. 37 and 38). See that pins and stop are secure, that flyweights operate freely, and that springs are not cracked or broken. Replace entire unit if a defect exists.

(10) Inspect magneto adapter oil seals. Install seals in the magneto adapter castings, using replacer 41–R–2392–995. Install tachometer drive driven gear seal. Lubricate all bearing surfaces with engine oil.

(11) Slip ignition advance unit assemblies and magneto drive gears into position over their ignition drive shafts. Install all gears in their respective bearings in the magneto adapters (figs. 37 and 38).

(12) Install tachometer drive cover, using new gasket, and secure with plain washers, plain nuts, and lock nuts.

(13) Install magneto drive subassemblies, using new gaskets between adapters and accessory case. The assemblies are secured with plain washers, plain nuts, and lock nuts.

(14) If starter and fuel pump drive assembly has been disassembled (fig. 39), it is reassembled as follows:

(*a*) Insert fuel pump drive gear (E) in starter hub (G) and drive in new pin (F). Make certain that pin is secure after installation.

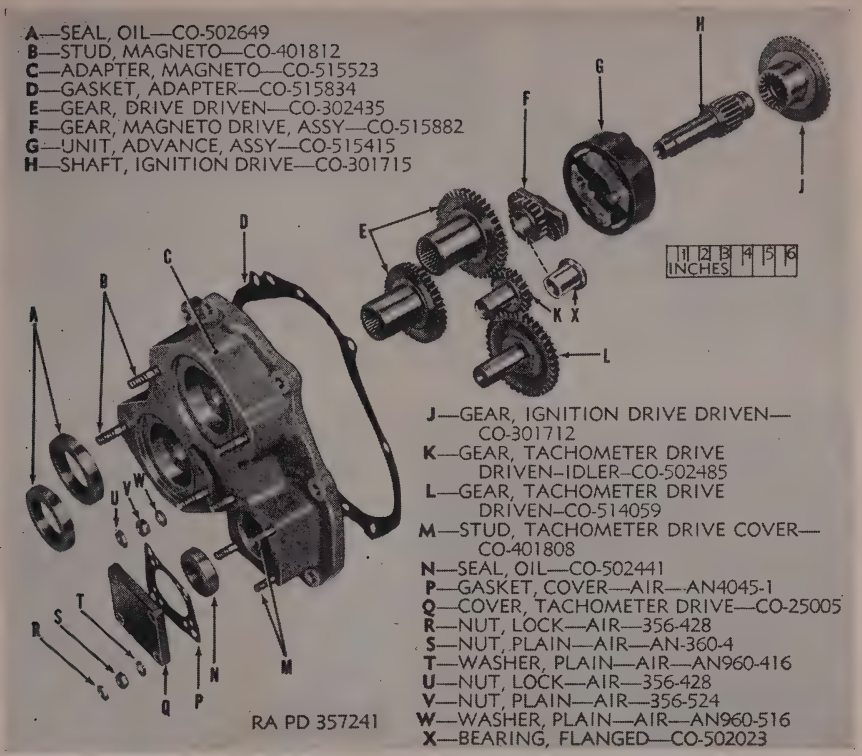


Figure 37. Magneto adapter, right-hand—exploded view.

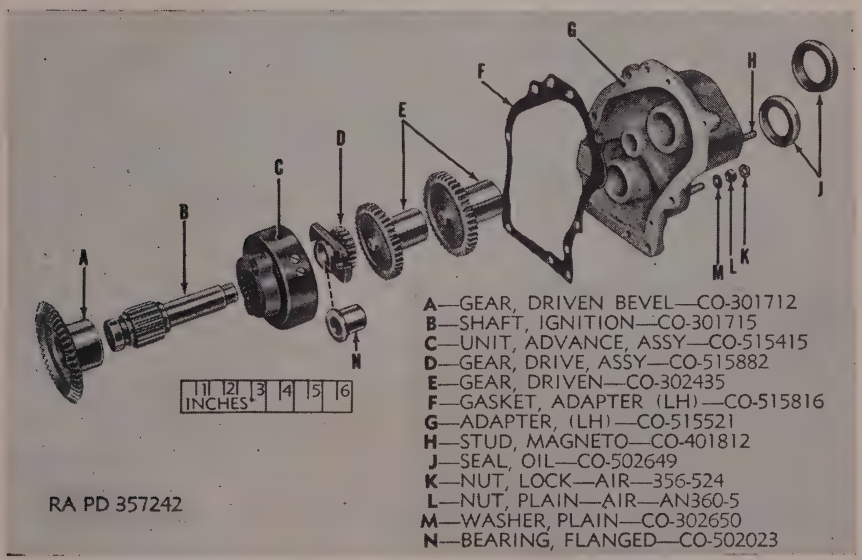
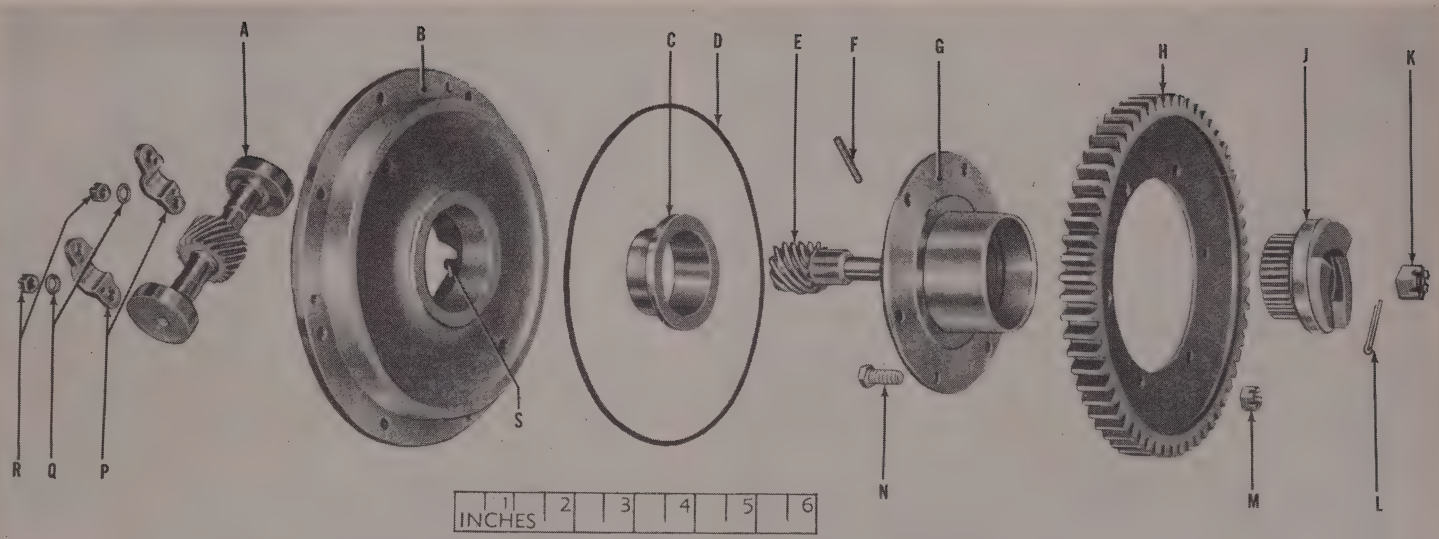


Figure 38. Magneto adapter, left-hand—exploded view.



A—GEAR, DRIVEN—CO-301742
B—ADAPTER, DRIVE SHAFT—CO-515673
C—BEARING, DRIVE SHAFT ADAPTER—CO-301748
D—GASKET, "O" RING—AIR—AN-6230-43
E—GEAR, DRIVE—CO-515508
F—PIN, DRIVE GEAR—CO-502124
G—HUB, STARTER DRIVE GEAR—CO-515520
H—GEAR, STARTER DRIVE—CO-301698
J—JAW, STARTER—CO-515517
K—NUT, SLOTTED—AIR—AN355-6
L—PIN, COTTER—AIR—AN380-2-4
M—NUT, SLOTTED—AIR—AN355-5
N—BOLT, HEX HEAD—CO-401367
P—CAP, DRIVE SHAFT BEARING—CO-515675
Q—WASHER, PLAIN—AIR—AN960-516
R—NUT, SLOTTED—AIR—AN355-5
S—STUD—CO-401811

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Figure 39. Starter and fuel pump drive—exploded view.

(*b*) Install starter jaw (J) and secure with slotted nut and cotter pin.

(*c*) Secure starter gear (H) to hub with hex-head bolts, slotted nuts, and locking wire.

(15) Insert starter and fuel pump drive assembly in accessory case and install fuel pump drive shaft adapter (B), using a new "O" ring gasket between adapter and case. Position fuel pump drive driven gear (A) in its bearings and install bearing caps (P). Secure caps with plain washers, slotted nuts, and locking wire. Install starter drive gear hub oil seal, using replacer (41–R–2388–715) (fig. 40).

Note. When installing gears, be sure that they mesh without interference.

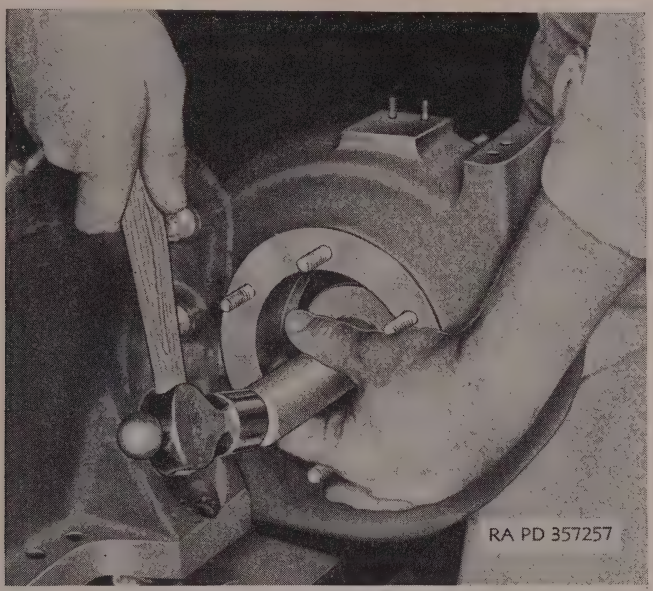

Figure 40. Installing starter drive gear hub oil seal with replacer (41–R–2388–715)

Section V. REBUILD OF CAMSHAFTS AND DRIVES

48. Disassembly of Camshafts and Drives (fig. 41)

a. Remove intercylinder connectors (D) from camshaft. Back off packing nuts (W), holding camshaft drive housings (Y) to outer supports (Z) and discard "O" ring gaskets (X).

b. Remove holding nuts from outer support flanges, pull supports (Z) from gear housings, discard "O" ring gaskets, and remove bevel gears (CC).

c. Remove bolts (L) holding camshaft gears (J) to camshafts (H), and remove oil retaining covers (K). Pull gears from camshafts and remove housings (G).

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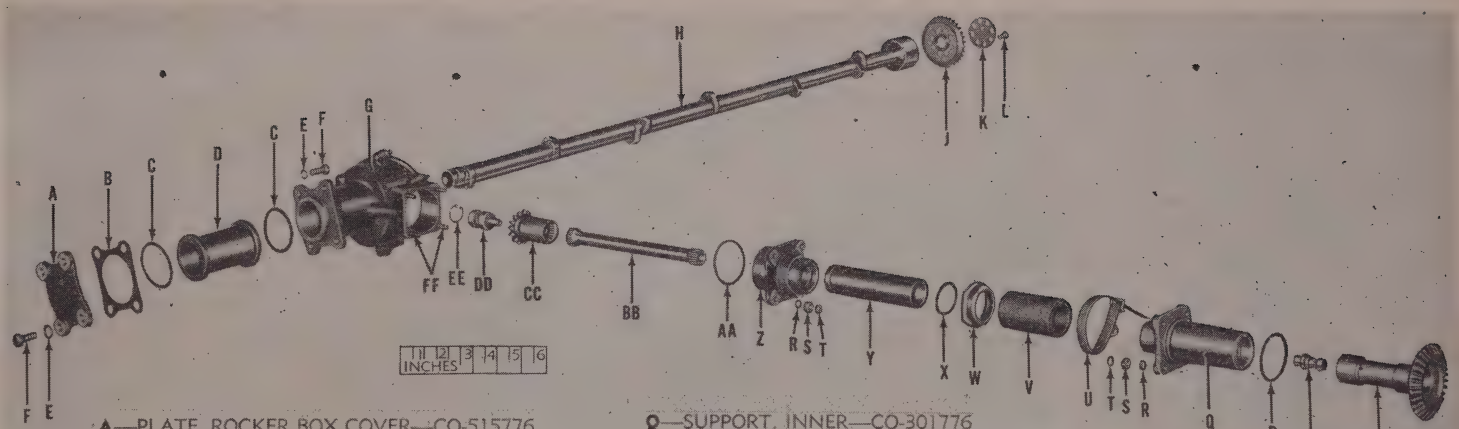


Figure 41. Camshaft and drive—exploded view.

49. Cleaning, Inspection, and Repair of Camshafts and Drives

a. Cleaning. Clean all parts thoroughly with dry-cleaning solvent or volatile mineral spirits paint thinner.

b. Inspection and Repair.

(1) Inspect castings, studs, gears, splines, quills, and oil passages (par. 46*b*).

(2) Check camshafts by magnaflux. If this equipment is not available, examine them with a magnifying glass for cracks. Examine lobes for scuffing and scoring. Light scuffing and scoring can be cleaned up with a hard Arkansas stone and polished with crocus cloth. Clean up any raised metal from any small nicks and abrasions elsewhere on the shaft with a hard Arkansas stone and crocus cloth. Check dimensions to limits specified in serviceability standards (pars. 118 and 119). Severely scuffed or scored shafts will be discarded.

(3) Check outer bevel gear oil transfer plugs. Adequate oil supply to camshafts and cylinder heads depends on the fit and condition of these plugs. See that oil passages are clean. Check plugs to serviceability standards (par. 120).

50. Assembly of Camshafts and Drives (fig. 41)

a. Note that camshafts and gear housings are right- and left-hand. The right-hand camshaft is slightly longer than the left. The right- and left-hand gear housings may be identified by setting the housings on the camshaft drive outer support studs. When facing the housing cover openings, the top side of the right-hand housing cylinder mounting pad slopes slightly up and to the right.

b. Attach camshaft gears (J) and oil-retaining covers (K) to

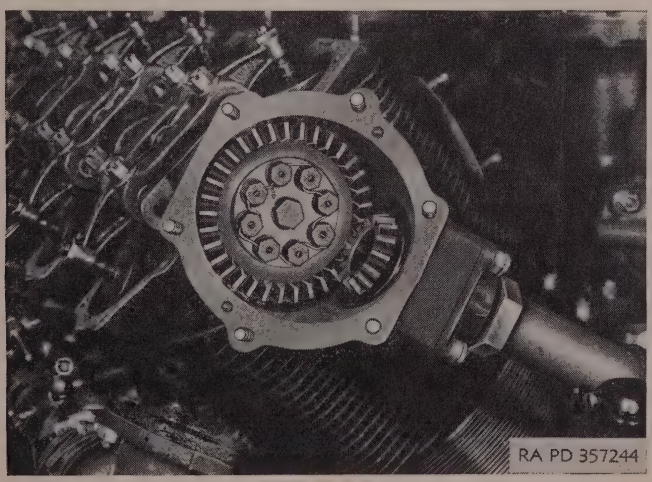


Figure 42. Camshaft gear secured with locking wire.

camshafts with special drilled head bolts. Secure assembly with locking wire (fig. 42). Lubricate all gears and bearings with engine oil.

c. Install new housing to cylinder head "O" ring gaskets on camshaft gear housing (G). Slide camshafts into housings to seat camshaft journals in their bearings. Be careful not to nick or damage camshaft lobes or journal bearings during this operation.

d. Install new "O" ring gaskets on camshaft drive outer supports (Z). Insert camshaft drive outer bevel gears (CC) in supports, and install supports in camshaft gear housings. Secure supports to housings with plain washers, plain nuts, and lock nuts.

e. Slip camshaft drive housing packing nuts (W) over housings (Y). Install new "O" ring gaskets over housings to inner side of the packing nuts. Insert camshaft drive housings into camshaft drive outer supports. Tighten packing nuts onto outer supports and secure with locking wire.

f. Slide camshaft drive inner-to-outer support hoses (V) over camshaft drive housings, and install two clamps (U) over each hose. Tighten clamps sufficiently to prevent falling from the hose.

Section VI. REBUILD OF COOLING FANS AND FAN DRIVES

51. Disassembly of Cooling Fans and Fan Drives

a. Cooling Fans (fig. 43).

(1) Separate fan rotor from clutch assembly by removing bolts from adapter and fan web.

(2) Remove bolts holding rotor adapter (C) to clutch assembly and separate parts.

(3) Remove external snap ring (P) from end of fan drive hub (K) and separate hub from outer clutch housing.

(4) Remove internal snap rings (L) from outer clutch housing (M) and push out ball bearing (N).

b. Cooling Fan Drives (fig. 44).

(1) The fan drive shafts (CC and FF), both drive bevel gear supports (G), and the vertical drive housings (A) were removed during prior disassembly (pars. 28, 39, and 40).

(2) Disassemble vertical drive housings as follows:

(*a*) Remove nuts holding oil seal housing (T) to vertical housing and lift off oil seal housing. Remove snap ring and oil seal retaining plate (U), and push out oil seal (S).

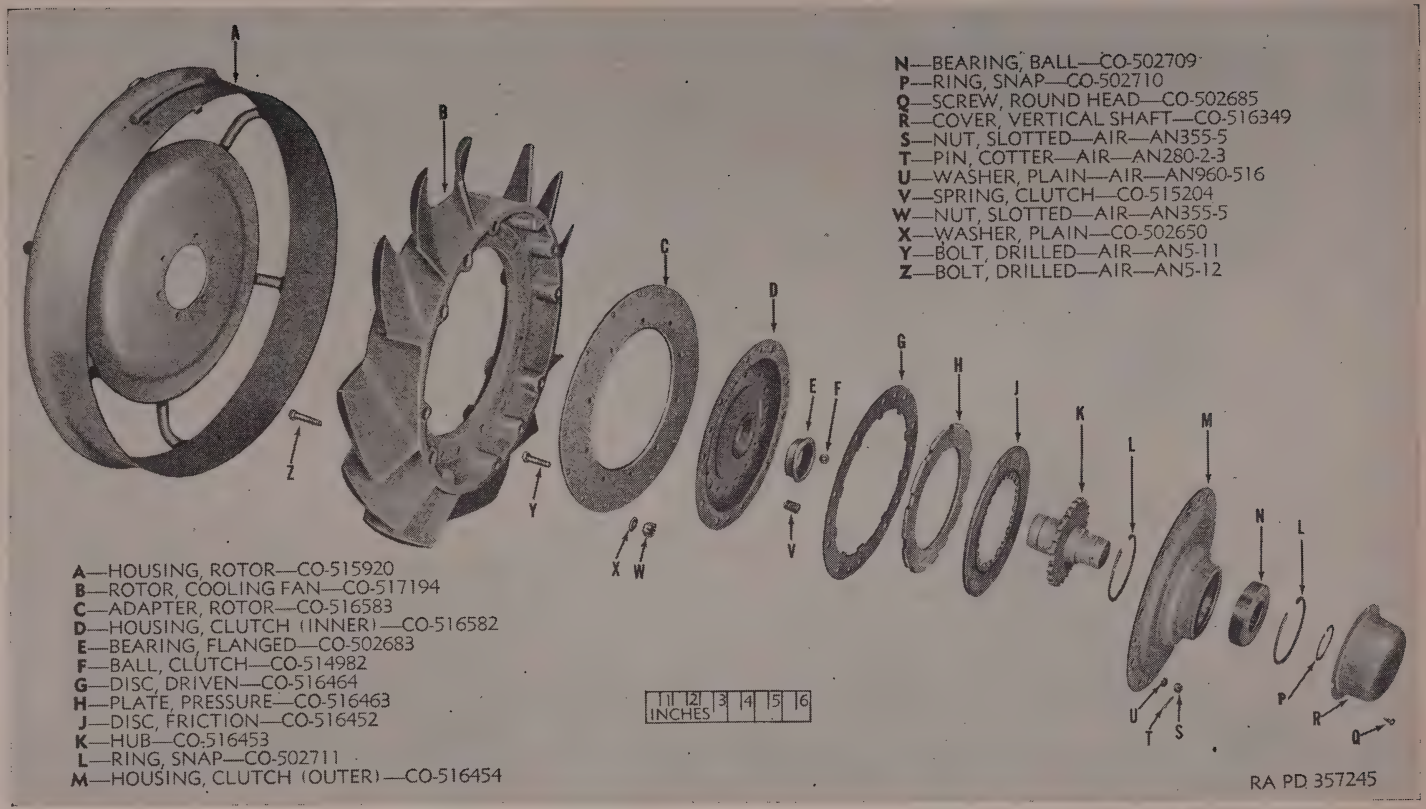
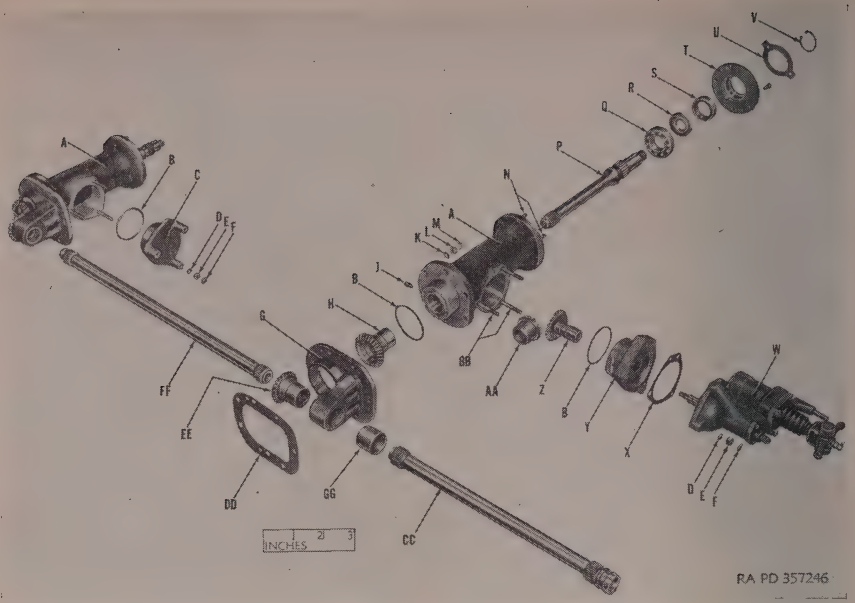


Figure 43. Cooling fan and clutch drive—exploded view.



A—HOUSING, FAN DRIVE—CO–515709
B–GASKET, "O" RING—AIR–AN6230–10
C—COVER, GOVERNOR ADAPTER—CO–301990
D—WASHER, PLAIN—AIR–AN960–516
E—NUT, PLAIN—AIR–AN360–5
F—NUT, LOCK—AIR–356–524
G—SUPPORT, DRIVE BEVEL GEAR—CO–515531 CO–515531
H—GEAR, BEVEL, DRIVEN—CO–516744
J—SCREW, SET—CO–301270
K—WASHER, PLAIN—AIR–AN960–616
L—NUT, PLAIN—AIR–AN360–6
M—NUT, LOCK—AIR–356–624
N—STUD, DRILLED—CO–401811
P—SHAFT, DRIVE, VERTICAL—CO–515490
Q—BEARING, BALL, SHIELDED—CO–301649
R—SPACER, HUB—CO–516443
S—SEAL, OIL—CO–502639
T—HOUSING, OIL SEAL—CO–515825
U—PLATE, RETAINING—CO–515831
V—RING, SNAP—CO–502632
W–GOVERNOR ASSY—CO–302321
X—GASKET, GOVERNOR—CO–301987
Y—ADAPTER, GOVERNOR—CO–301989
Z—GEAR, BEVEL, DRIVEN—CO–301981
AA—GEAR, BEVEL, GOVERNOR DRIVE—CO–516103
BB—STUD, GOVERNOR—CO–401883
CC—SHAFT, HORIZONTAL, ASSY (ACCESSORY END)—CO–414591
DD—GASKET, GEAR SUPPORT—CO–515964
EE—GEAR, BEVEL, FAN DRIVE—CO–517298
FF—SHAFT, HORIZONTAL, ASSY (FLYWHEEL END)—CO–515493
GG—BEARING, FAN DRIVE BEVEL GEAR SUPPORT—CO–302779

Figure 44. Cooling fan drive—exploded view.

(*b*) Lift out vertical drive shaft (P) and remove fan hub spacer (R), ball bearing (Q), and governor drive bevel gear (AA).

(*c*) Remove retaining set screw (J) from the finished extension of the vertical housing, and pull out driven bevel gear (H).

(*d*) Remove governor adapter replacement cover (C) from flywheel end vertical housing.

52. Cleaning, Inspection, and Repair of Cooling Fans and Fan Drives

a. Cleaning.

(1) *General.* Clean all castings and machined parts with dry-cleaning solvent or volatile mineral spirits paint thinner.

(2) *Bearings.* Clean ball and roller bearings thoroughly with dry-cleaning solvent. Rotate them on the fingers and tap to dislodge any clinging dirt. Flush in clean fluid and blow dry.

Note. Never spin a bearing with an air blast while cleaning or drying.

Oil bearing with light engine oil and spin with fingers to detect any slight roughness. Check ball bearings for noticeable end play. End play is evidence of wear. Replace all worn or rough bearings. If bearings are to be kept for an indefinite period before installation, they must be protected by coating with rust-preventive compound. Normal lubricating oil is not adequate.

Note. The above cleaning does not apply to sealed bearings. Such bearings are packed with lubricant sufficient for the life of the bearing. Wipe them clean using a cloth dampened with solvent, if necessary, but do not dip bearing in solvent.

b. Inspection and Repair.

(1) *Cooling fan drives* (fig. 44).

(*a*) Inspect fan drive housing (A), fan drive bevel gear support (G), fan drive oil seal housing (T), and governor adapters (Y), as outlined in paragraph 46*b* (1) and (2). Inspect gears (par. 46*b* (3)) and bearings (par. 46*b* (6)).

(*b*) Inspect pilots on ends of fan drive horizontal shaft assemblies. See that they are in good condition and that oil passages line up accurately with those in fan drive bevel gears and accessory driven shaft. See that plug in one end of each horizontal shaft is installed securely.

(*c*) Inspect all parts to the limits in serviceability standards (par. 122).

(2) *Fan drive bevel gear supports* (fig. 44).

(*a*) Inspect the supports (G) as outlined in paragraph 46*b* (1) and (2). Replace defective studs (par. 46*b* (2)).

(*b*) Check the bushings against serviceability standards (par. 126). These bushings are replaceable. Bore out the defective bushing to a thin shell, collapse, and remove it. Grind off the projecting portion of the retaining pins. Install replacement bushing and secure with two pins.

(3) *Cooling fan and clutch* (fig. 43).

(*a*) The cooling fan rotors should be inspected for cracks, nicks, and scratches. Remove raised portions of metal caused by nicks and scratches with a fine mill file. Any crack is cause for rejection of the fan. Do not straighten bent blades. If judgment indicates that a blade is bent sufficiently to impair cooling, replace fan.

(*b*) Inspect rotor adapter (C) for distortion. See that the mounting flange is flat and free from raised metal or dents and scratches. The centering pilot must be without nicks or abrasions that would interfere with a neat fit in the fan rotor.

(*c*) Inspect cooling fan rotor housing (A) for cracks and deformation. Repair cracks by welding. Deformation will be indicated by scratches and gouges on the inner surface of the housing where fan has rubbed. These areas should be reshaped to provide clearance.

(*d*) Inspect friction disc (J), pressure plate (H), and clutch housings (D and M) for imperfections and signs of failure. There are no definite limits established for these parts and good judgment must decide if parts are to be replaced. Inspect bearings (*a* (2) above). Parts should be checked to the limits in serviceability standards (par. 122).

53. Assembly of Cooling Fans and Fan Drives

a. Fan Clutch and Rotor (fig. 43).

(1) Insert ball bearing (N) in clutch outer housing (M) and secure with an internal snap ring (L) on each side of the bearing. Use pliers (41–P–1992–36) to install snap rings.

(2) Position inner clutch housing assembly (D) and pressure plate driven disc (G) over fan rotor adapter dowel pins. Install 15 balls (F) and 3 springs (V) in their inner housing recesses.

(3) Lay clutch pressure plate (H) on clutch springs with its serrations alined to mesh with those of the driven pressure plate. Lay friction disc (J) on pressure plate and concentric with it. Push fan hub (K) through ball bearing and mesh its serrations with those of friction disc.

(4) Install outer housing assembly (M) over fan hub and gently compress assembly until outer housing engages fan rotor adapter dowel pins. Keep assembly compressed until secure to fan rotor.

Caution: Never force the fan clutch assembly when compressing it. The hub and plate serrations can be damaged badly if they get out of line and heavy compression forces are applied.

Secure the clutch assembly to the fan rotor adapter with drilled bolts, plain washers, slotted nuts, and cotter pins. Install bolts with bolt heads in contact with fan rotor adapter.

(5) Install snap ring (P) over fan drive hub.

(6) Install clutch and adapter assembly on the top side of fan rotor. Note that the rotor web is finished on the top side; also, that fan blades taper to a thin edge at top side. A centering pilot on adapter must be entered in the rotor web and the adapter flange seated on the web before drawing up the bolts. Secure the adapter to the rotor with drilled bolts, plain washers, slotted nuts, and cotter pins.

b. Fan Drive Housings (fig. 44).

(1) Lubricate all gears and bearings with engine oil. Install ball bearings (Q) on fan drive vertical shafts with shielded side up. Insert governor drive bevel gear (AA) in the bearing of accessory end fan drive housing. Install shafts and bearings in housings. Be sure bearings are seated in housings (A). Place cooling fan hub spacers (R) over vertical shafts, resting on bearings.

(2) Insert new cooling fan drive oil seals (S) in oil seal housings (T) and secure with oil seal retaining plates (U) and internal snap rings (V), using pliers (41–P–1992–36). Install housing and seal assemblies on top of fan drive housings and secure with flat head machine screws.

(3) Install fan drive driven bevel gears (H) and secure with gear-retaining set screws (J).

(4) Install governor adapter replacement cover (C) on flywheel and fan drive housing, using a new "O" ring gasket, and fasten cover with plain washers, plain nuts, and lock nuts.

(5) Insert governor drive driven bevel gear (Z) in governor adapter (Y) and install adapter on the fan tower. Use new "O" ring gasket on the adapter. Install new governor gasket and the governor, securing the adapter and governor to the fan tower with plain washers, plain nuts, and lock nuts.

(6) Install new "O" ring gaskets (B) around bevel gear end of both fan drive housings.

Section VII. REBUILD OF CYLINDERS

54. Disassembly of Cylinders (fig. 45)

a. Remove spark plugs; clean, inspect, and repair. Refer to pertinent operator's manual.

b. Remove camshaft bearing cap and rocker support bracket. Remove valve springs with compressor (41–C–2558–900). Place compressor on the cylinder head studs and secure with nuts on the two studs nearest the spring being removed (fig. 46). Hold the valve against its seat with one hand and turn down compressor screw until cone-shaped locks can be lifted out. Tap compressor if locks tend to stick. Release compressor, lift out valve springs, retainer, spring seat, and valve. Reinstall camshaft bearing cap and rocker support bracket in original positions.

55. Cleaning, Inspection, and Repair

a. Cleaning.

(1) Clean all parts thoroughly with dry-cleaning solvent or volatile mineral spirits paint thinner.

(2) Remove heavy carbon deposits from combustion chambers with a conventional scraper or any blunt tool which will not nick or scratch the surfaces. The surfaces need not be cleaned to a mirror finish; it is necessary only to remove heavy deposits.

b. Inspection.

(1) *Oil passages.* Check oil passages in the camshaft bearing and caps and make certain they are clean.

(2) *Cylinder.* Check the surface of the cylinder bore for deep scratches or scoring. With an inspection mirror, examine joint between cylinder head and barrel. Scrap cylinder if erosion is evident.

(3) *Bore inspection.*

(*a*) Check the bore dimensions to the specified limits in serviceability standards (par. 124). If cylinder is not to be rehoned and is to be reinstalled with new set of rings, rough-up bore surface by hand with 80-grit emery cloth.

Note. After honing, roughing-up with emery cloth, or any use of an abrasive, wash the cylinders thoroughly to be sure they are free from all trace of the abrasive.

(*b*) Cylinder bores are tapered slightly when at room temperature. This results in a bore which essentially is straight when hot.

(*c*) With cylinder at room temperature, take two measurements of bore diameters at top of ring travel, one measure-

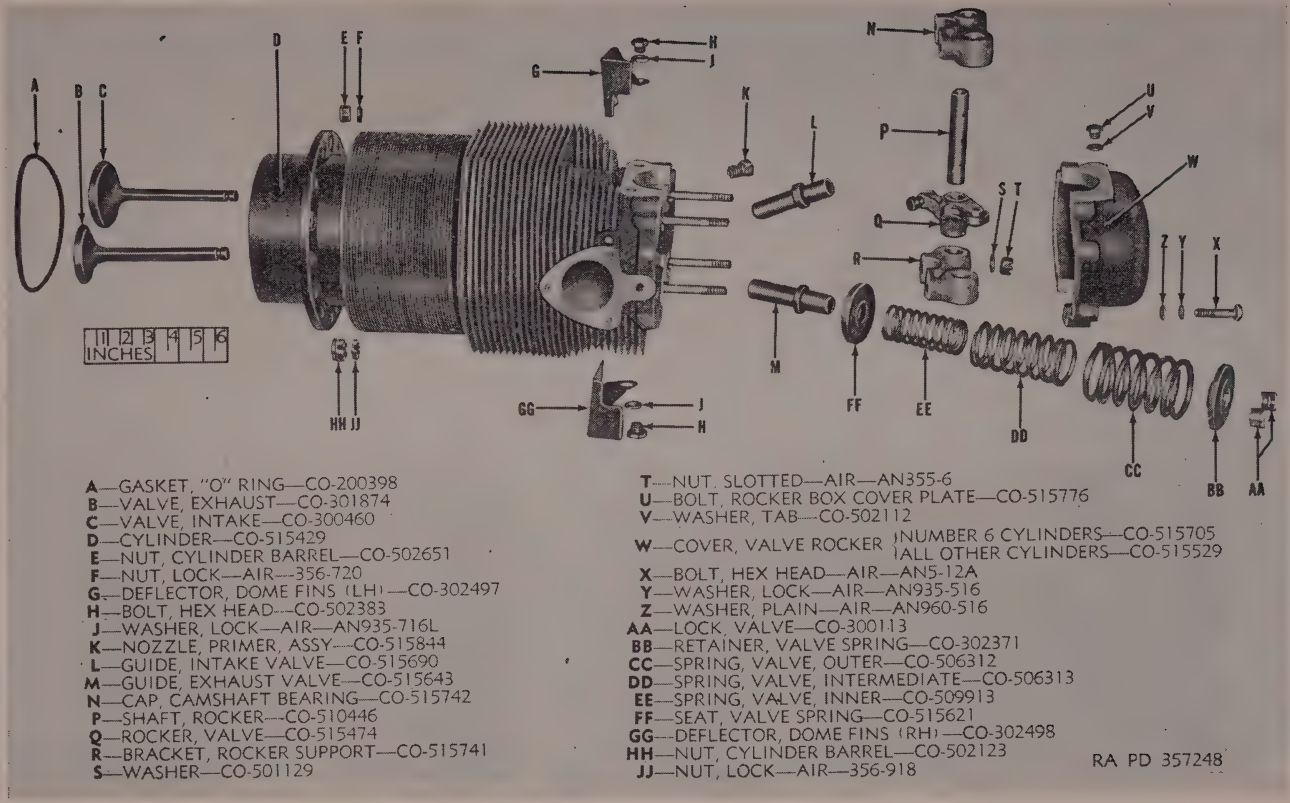


Figure 45. Cylinder assembly—exploded view.

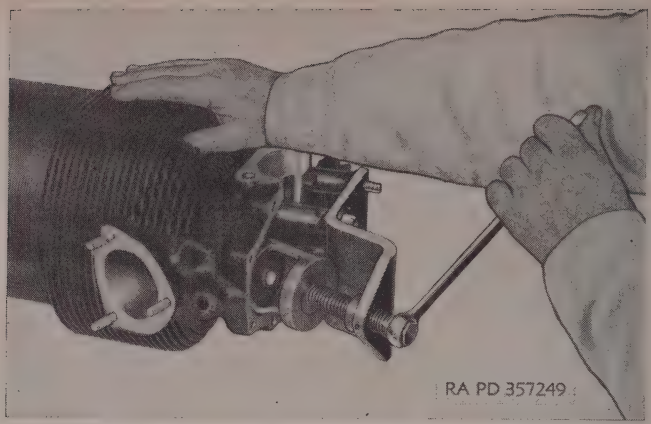


Figure 46. Compressing valve springs with compressor (41–C–2558–900)

ment parallel to the valves, the other at 90° to the first.

(*d*) Next, check bore diameter at the flange end of the cylinder, parallel to the valves and at the point of deepest ring wear. Make a second measurement at 90° to the valves and at the point of deepest ring wear.

(4) *Diagnosis.*

(*a*) Check the taper by comparing the average measurements of (3) (*c*) and (*d*) above. If the head end average is greater than the flange end, rehone cylinder.

(*b*) Compare the two measurements taken at the head end. If difference shows out-of-round more than 0.003 inch, rehone cylinder. If diameter at head end, after honing, is more than 5.7537 inches, replace cylinder.

(5) *Ring ridge.* Check for ring ridge by running finger over cylinder wall. If a ridge can be felt at the end of ring travel, either at the top or bottom of cylinder, it should be rehoned.

(6) *Valve guides.* Inspect valve guides for looseness, cracks, galling, erosion, or scuffing. Clean out any carbon deposit in the bores with crocus cloth and dry-cleaning solvent. Check bores to the limits in serviceability standards (par. 139), and replace if necessary.

(7) *Valve seat inserts.*

(*a*) It is very important that valve seat inserts are seated tightly in cylinder head. Inspect carefully for any signs of loosening. Loose inserts must be removed and new ones installed.

(*b*) If inserts are not to be replaced, inspect the seats and regrind (fig. 50) if any sign of pitting or burning is found.

(*c*) Test valve seats for imperfect seal. Blue the face of valve seat with Prussian blue, install a perfect valve, and rotate

it on the seat one-half turn. If valve does not show perfect contact, regrind seat (fig. 50).

(8) *Valves, valve springs, and retainers.*

(*a*) Check valves for evidence of imperfect seating. Heavy discoloration, burning or erosion, or a deposit of carbon on valve face is indication of a warped valve. Light frosting or discoloration of the shiny face of the valve should not be cause for replacement if the valve otherwise appears to be in good condition. Valves seat much better at operating temperatures than normally is indicated by inspection of a cold valve, and these minor discolorations usually appear after stopping the engine and valve begins to cool. Examine stems and locking grooves for wear, scoring, pitting or other damage. Make certain that tips are not cracked or damaged. Check stem diameters to the limits specified in serviceability standards (par. 138).

(*b*) Inspect valve springs for cracks, flaws, or other visible evidence of failure. Check all springs for compression as given in serviceability standards (par. 142).

(*c*) Check valve spring retainers and seats for wear or signs of failure. Check the tapered seat for the valve locks in the retainers. These locks are split and wear may be noted by ridges left between the halves of the locks. Replace all worn parts.

(9) *Camshaft bearings.* Remove raised metal from light scores or scratches in the camshaft bearings with a fine mill file. Check bearings to serviceability standards (par. 119).

c. Repair.

(1) *Cylinder fins.* Straighten bent fins on the barrel to the original spacing as nearly as possible. Notice condition of head fins. If number of broken or missing fins is considered to be enough to affect the cooling materially, cylinder should be replaced.

(2) *Replacing valve guides.*

(*a*) To remove a valve guide, insert remover ((41–R–2371–30) for intake valve guides and (41–R–2371–15) for exhaust valve guides) into guide. Support cylinder so that fins will not be damaged and drive guide out of cylinder head (fig. 47).

(*b*) Replacers ((41–R–2390–478) for the intake valve guides and (41–R–2390–473) for the exhaust valve guides) are provided for installing replacements. To install a guide, pull loose ferrule from end of replacer and place valve guide over tool, entering the short end of guide into hollow tool handle. Replace ferrule to retain the guide. Enter ferrule in the bore for the value guide and drive guide to

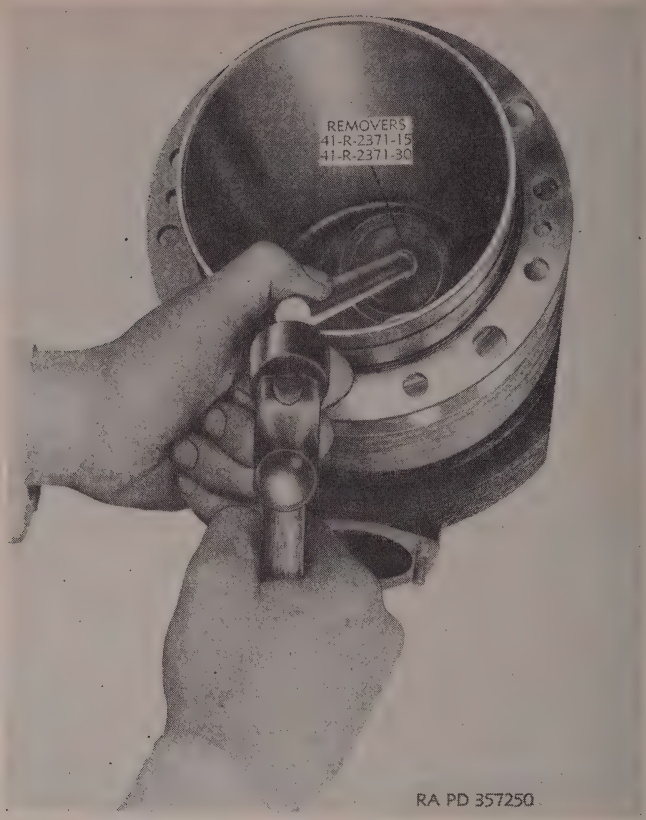


Figure 47. Removing valve guides.

its seat (fig. 48). Withdraw the replacer and replace the loose ferrule on the tool.

(*c*) Rough and finish reamers and reamer pilot bushings are provided for conditioning replaced guides.

1. For exhaust valve guides, use—

Pilot bushing (41–B–2181–150)
Roughing reamer (41–R–2254–565)
Finishing reamer (41–R–2254–515)

2. For intake valve guides, use—

Pilot bushing (41–B–2181–175)
Roughing reamer (41–R–2254–550)
Finishing reamer (41–R–2254–500)

(*d*) To ream valve guides, insert pilot bushing in valve seat insert. While an assistant holds pilot bushing in place, rough and finish ream valve guide.

(3) *Replacing valve seat inserts* (fig. 49).

(*a*) A remover kit (41–R–2371–465) (fig. 6) is used to remove and replace valve seat inserts. The kit is, essentially, a

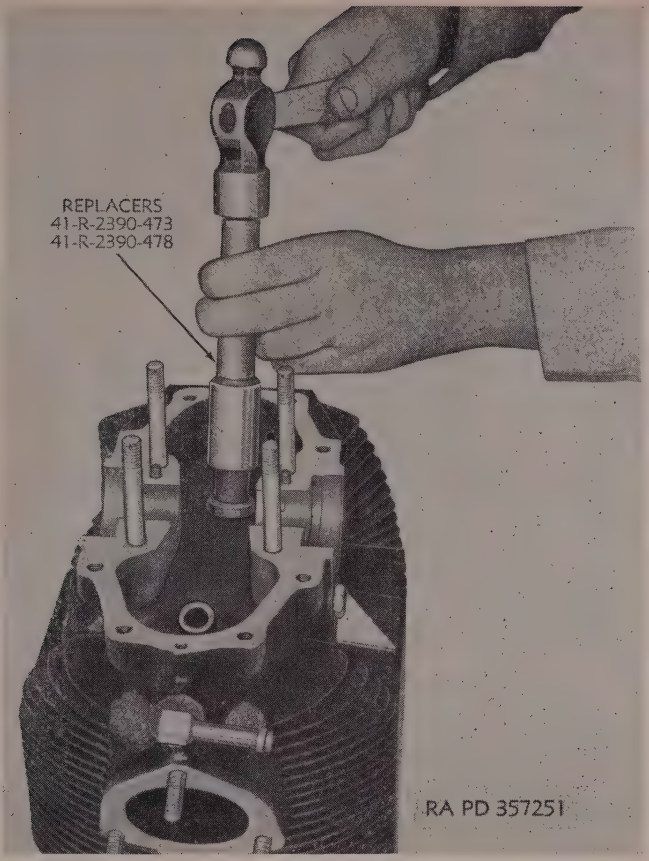


Figure 48. Installing valve guides.

drawbar collet set, modified to permit the use of CO_2 (carbon dioxide) gas which lowers the collet to an extremely low temperature. Two collets are provided, one for intake and one for exhaust valve seat insert. In use, the appropriate collet is placed on the drawbar, the cylinder heated, and the collet assembly inserted and expanded in the insert. Gas from a CO_2 cylinder is admitted to an expansion chamber in the collet cone; then the chilled insert is removed.

(*b*) To remove an insert, place the proper size collet on the collet arbor and screw the cone expander into the arbor. Connect the hose, furnished with the kit, to a CO_2 cylinder, and arrange it so the quick detachable fitting may be attached to extension tube of collet without delay. Heat cylinder to between 450° and 500° F. Insert collet assembly into valve seat insert from open end of cylinder, seat the collet, and expand it to the limit by the handwheel.

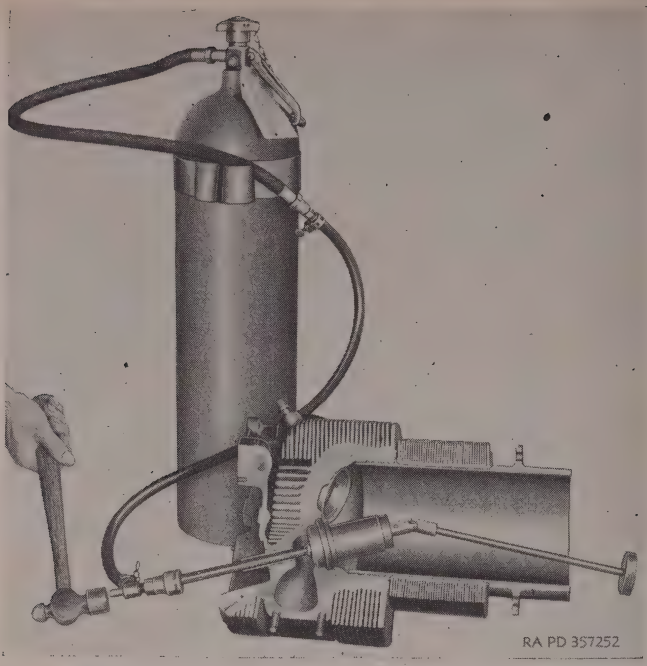


Figure 49. Removing valve seat inserts with remover kit (41–R–2371–465).

Attach the hose fitting to the tube extending from the cylinder head and open CO_2 valve for 10 to 15 seconds to shrink insert. Strike extension on gas fitting with a hammer to dislodge insert, detach the gas fitting, and withdraw the insert while still on the collet. Figure 49 shows the arrangement for removal.

(*c*) To replace an insert, reheat cylinder, place insert on collet, and turn handwheel to hold insert in place. Attach the CO_2 fitting and chill insert. Detach the gas fitting, insert the assembly, and seat the insert securely. Release the collet and remove the fixture after the cylinder temperature has approached normal.

Caution: Asbestos gloves always should be worn while replacing inserts. Severe burns can result from the heated cylinders as well as the low temperature of the tool.

(*d*) Oversize seat inserts (0.010 in. and 0.020 in.) are supplied as replacements for loose inserts.

(*e*) Before refacing valve seats, be certain that grinding stones are true to 45° angle. Dress seats and check valve contact (*b* (7) above). When perfect contact is obtained, narrow seat width by grinding the surface and the inner walls (fig. 50). Keep seat as near center of valve face as pos-

sible. Check valve contact again after seat width is obtained.

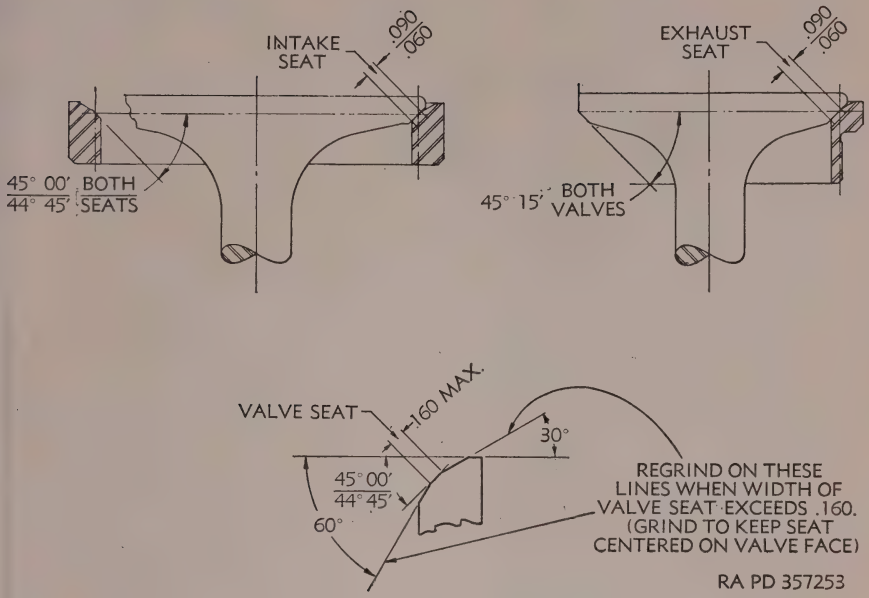


Figure 50. Diagram of valve and seat grinding.

56. Assembly of Cylinders

a. Install valve spring compressor (41–C–2558–900) (fig. 46) on rocker cap studs. Insert valve in its guide and assemble valve spring seat, three valve springs, and spring retainer. Compress spring assembly sufficiently to permit installation of valve locks in valve stem recess. Replace each camshaft bearing cap and rocker support bracket on its original cylinder.

b. Assemble the cylinder air deflectors (A) (fig. 16) with lock washers and bolts in all except the outside positions of Nos. 1 and 6 cylinders. Replace any deflectors which are cracked.

c. All cylinders are marked on the intake side of the mounting flange, showing original installation position. Replacement cylinders must be marked similarly.

Section VIII. REBUILD OF OIL PUMP

57. Disassembly of Oil Pump (fig. 51)

Lift oil pump driven bevel gear from housing. Remove bolts holding housings together. Remove bolts and lock plate holding driven impeller shaft in position. Separate housings, remove driven impellers from their shaft, and withdraw shaft from separator plate.

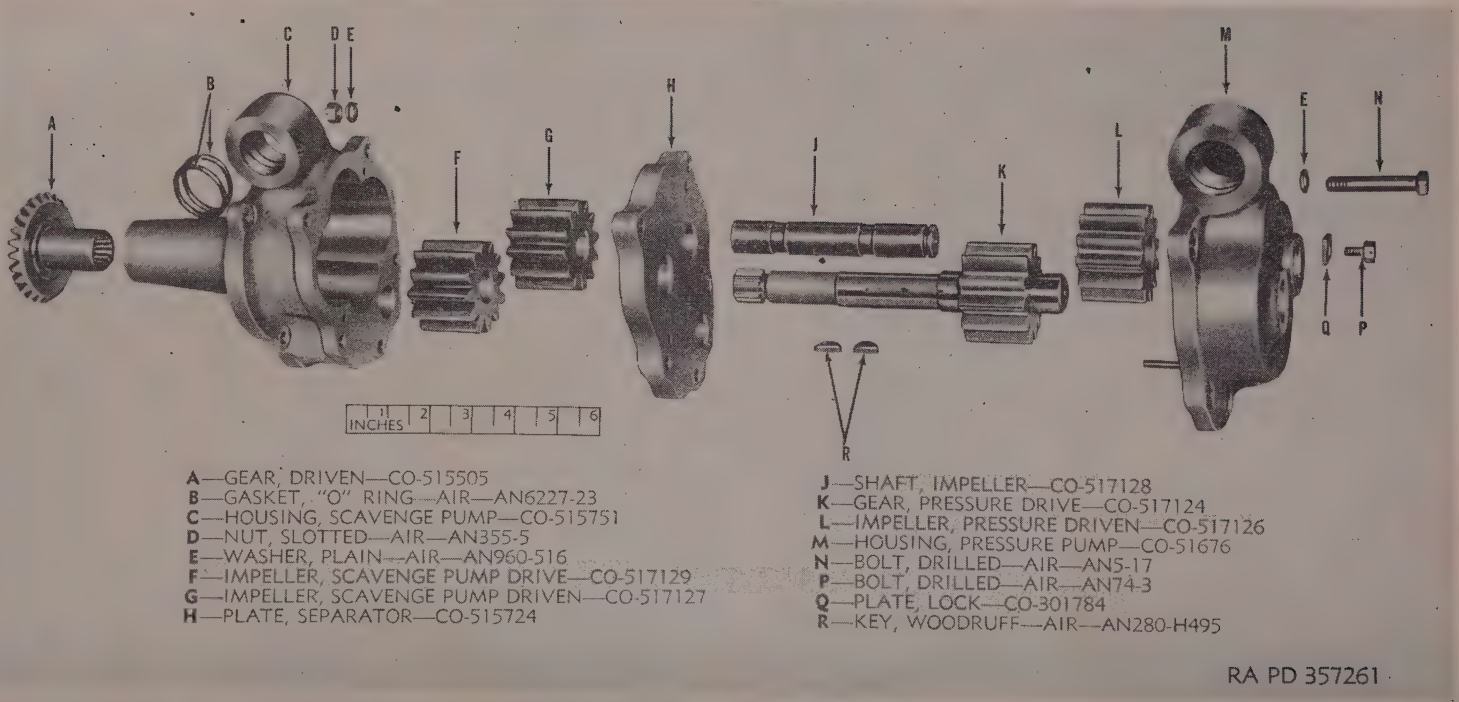


Figure 51. Oil pump—exploded view.

Slide scavenge pump drive impeller off gear shaft and remove Woodruff keys. Lift separator plate off gear shaft and remove gear.

58. Cleaning and Inspection

a. Cleaning. Clean all parts with dry-cleaning solvent or volatile mineral spirits paint thinner.

b. Inspection.

(1) Examine mounting surface of pump and all mating surfaces for nicks or scratches. Remove any raised metal with a fine mill file. No gaskets are used on these surfaces and they must be free from all imperfections which would impair a tight oil seal.

(2) Inspect gears and shafts by magnaflux. If this method is not available, inspect them with a magnifying glass for cracks. Cracked parts are defective. (See (5) below.)

(3) Examine gears for abrasions on tooth faces and for burs on tooth corners.

(4) Examine shafts for scoring or galling.

(5) Pump parts are not interchangeable. Any pump with defective parts must be replaced with a new pump assembly. Good judgment must be used in cases of minor or questionable imperfections.

(6) Check all parts to the limits in serviceability standards (par. 134).

59. Assembly of Oil Pump (fig. 51)

a. Install the driven impeller shaft (J) in the pressure pump housing (M), and secure it with the lock plate (Q), drilled head bolt, and locking wire. Lubricate all gears, shafts, and bearings with engine oil.

b. Slip the pressure pump driven impeller (L) into position on the shaft and install the pressure pump drive gear (K).

c. Install the oil pump separator plate over the two shafts and the pressure to scavenge housing dowel pins.

d. Insert the Woodruff keys in the drive shaft and install the scavenge pump drive impeller (F) over it. Slip the scavenge pump driven impeller (G) onto the driven impeller shaft.

e. Install the scavenge pump housing and secure it to the pressure pump housing with drilled bolts, plain washers, slotted nuts, and locking wire.

f. Install new "O" ring gaskets (B) in the grooves of the pump ports. Slip the oil pump driven bevel gear into its bearing.

Section IX. REBUILD OF CRANKCASE

60. Cleaning, Inspection, and Repair of Crankcase (fig. 52)

a. Cleaning.

(1) Wash crankcase and crankshaft oil seal housings thoroughly with dry-cleaning solvent or volatile mineral spirits paint thinner.

(2) Remove pipe plug (UU) from end of main oil gallery at flywheel end and the plugs and sending units from side of crankcase opposite main bearings. Flow clean dry-cleaning solvent through oil passages. Use probes, if necessary, to dislodge sludge deposits. Passages must be clean.

b. Inspection.

(1) Carefully examine crankcase and crankshaft oil seal housings for cracks with the aid of a strong light or the latest process available. Small cracks probably will lead to greater difficulty during subsequent operation of the engine. Castings in which cracks are found must be replaced. Inspect areas surrounding main bearing supports for breaks or flaws.

(2) Note condition of mating flanges and mounting pads (par. 46*b*). Examine the cylinder mounting pads and locating bores for any damage caused by careless removal of crankshaft and connecting rods.

(3) Check studs. Mark for replacement all loose or bent studs, or studs with damaged threads.

(4) Reinstall and bore-check main bearings.

(*a*) Be sure that bearings are clean and that oil holes are open. Use a wooden pin or sliver to clean out any sludge accumulation from oil groove. A hard or sharp-edged tool easily can damage soft bearing metal.

(*b*) The inspection of bearing surfaces cannot be specified exactly; it is, therefore, largely a matter of judgment and experience. The following general statements will assist in determining whether a bearing is serviceable or should be replaced:

1. If the bearing surface shows signs of separating from the underlying metal, the bearing must be replaced.

2. Scratches on the bearing surface are not cause for rejection unless the surface area destroyed is over 5 percent of bearing face. Bearings showing raised metal at edges of the scratches must be replaced.

3. Some loss of bearing metal from the grid pockets is not an unusual condition and is not cause for rejection unless the area affected is over 25 percent of total area.

4. Small particles of foreign matter, embedded in the bearing surface, are not cause for rejection and no attempt should be made to remove them. However, if a concentration of embedded particles affects 5 percent of the surface, the bearing will be replaced.

5. The seriousness of the above defects is, of necessity, a matter of good judgment. Replace any bearing if there is any doubt of its serviceability.

(*c*) Check the bearing thickness to the limits specified in serviceability standards (par. 131).

(*d*) Preserve the identification markings. Main bearings must be installed in their original positions and usually are etched on the steel back. Renew the marks with a grease pencil, if defaced. Never use a scriber or a sharp tool to mark bearings.

(*e*) Install a stud driver and, without loosening any studs, apply a torque of 700 inch-pounds to all main bearing studs (fig. 53).

(*f*) Pinch-check and bore-check main bearings as follows:

1. Spread thin coating of Prussian blue over the steel backs of the bearings and assemble in their original locations in crankcase and main bearing caps. Install caps, special washers and cap nuts. On each bearing, pull up one cap nut to 1,250 inch-pounds torque (fig. 73). Insert a 0.001-inch feeler gage in the opposite joint and pull up cap nut until it begins to pinch feeler gage. The torque necessary to pinch gage should be between 450 and 850 inch-pounds. If torque is not within this range, install a new bearing and repeat the check.

2. Remove feeler gage and pull up cap nut to 1,250 inch-pounds torque. Check the bore diameter to limits specified in serviceability standards (par. 131).

3. Disassemble and check bearing contact with crankcase bore as shown by the blue transfer. Bearings must make 75 percent contact.

4. Set the thrust bearing halves back into center main bearing and cap, and check clearance between thrust bearing flange and bearing and cap faces. If clearance is less than 0.002 inch, replace the bearing.

c. Repair.

(1) *Replace defective studs* (par. 46*b*).

(2) *Replace defective "Rosan" inserts.*

(*a*) To permit higher stresses in studs which are set in aluminum castings, it is common practice to install inserts of a more substantial metal into which the studs are threaded.

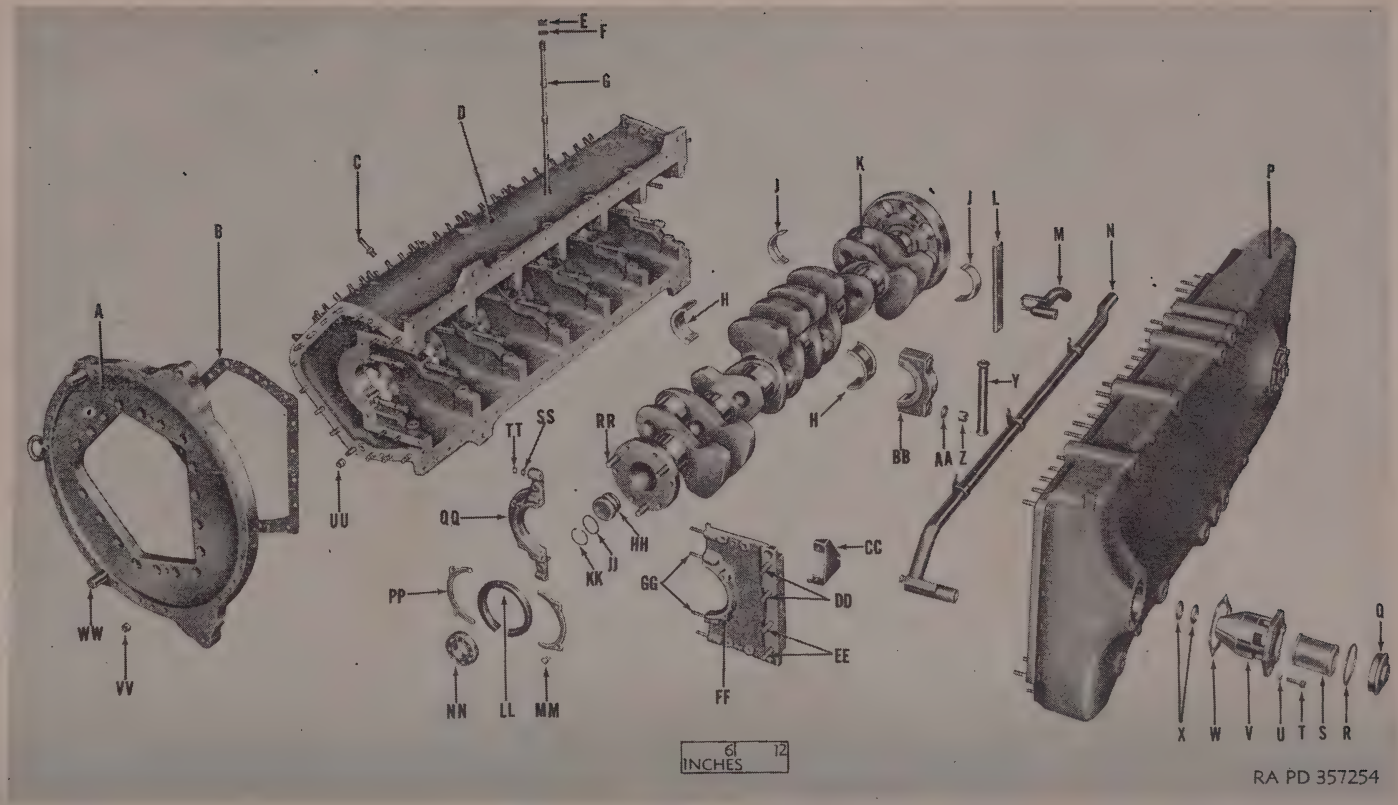


Figure 52. Crankcase—exploded view.

A—ADAPTER, TRANSMISSION CASE—CO–515693
B—GASKET, ADAPTER—CO–515622
C—ADAPTER, ROCKER BOX OIL DRAIN LINE—AIR–AN840–8
*D—CRANKCASE—CO–515419
E—NUT, SPECIAL—CO–505010
F—WASHER, PLAIN—CO–502609
G—BOLT, CROSS, CRANKCASE—CO–301076
*H—BEARING, CRANKSHAFT THRUST—CO–302409
*J—BEARING, CRANKSHAFT MAIN—CO–301750
K—CRANKSHAFT—CO–516745
L—BRACKET, PRESSURE OIL LINE SUPPORT—CO–302347
M—LINE, PRESSURE OIL PUMP INLET, ASSY—CO–302345
N—LINE, SCAVENGE OIL PUMP INLET, ASSY—CO–302349
P—PAN, OIL—CO–515417
Q—PLUG, OIL SUMP SCREEN—CO–302335
R—GASKET, ANNULAR—AIR—AN900–46
S—SCREEN, OIL SUMP, ASSY—CO–302338
T—BOLT, DRILLED HEAD—CO–401371
U—WASHER, PLAIN—AIR—AN960–516
V—HOUSING, OIL SUMP SCREEN—CO–302348
W—GASKET, SCREEN HOUSING—CO–302357
X—GASKET, "O" RING—AIR—AN6227–23
Y—SPACER, CRANKCASE CROSS BOLT—CO–301077
Z—NUT, MAIN BEARING CAP—CO–509272
AA—WASHER, MAIN BEARING CAP—CO–509273
BB—CAP, MAIN BEARING—CO–301052
CC—BRACKET, SCAVENGE OIL LINE SUPPORT—CO–302584
DD—STUD, TRANSMISSION ADAPTER—CO–515949
EE—STUD, DRILLED—CO–401876
*FF—HOUSING, CRANKSHAFT OIL SEAL, LOWER—CO–515639
GG—STUD, DRILLED—CO–401931
HH—PLUG, CRANKSHAFT, FLYWHEEL END—CO–515459
JJ—GASKET, "O" RING—AIR—AN6227–25
KK—RING, SNAP—CO–401665
LL—SEAL, OIL—CO–502535
MM—BOLT, DRILLED HEAD—AIR—AN74–3
NN—BEARING, BALL, TRANSMISSION SHAFT PILOT—CO–301273
PP—PLATE, OIL SEAL RETAINING—CO–515582
*QQ—HOUSING, OIL SEAL (UPPER)—CO–515581
RR—PIN, DOWEL—CO–502097
SS—WASHER, PLAIN—AIR—AN960–516
TT—NUT, SLOTTED—AIR—AN355–5
UU—PLUG, PIPE—CO–401756
VV—NUT, SLOTTED—AIR—AN355–7
WW—PIN, DOWEL—CO–502119

Figure 52.—Continued.

*D includes H, J, and FF (FF includes QQ). D (casting only)—CO–515420; FF (casting only)—CO–515580. These parts are machined in assembly and must be replaced as a group.

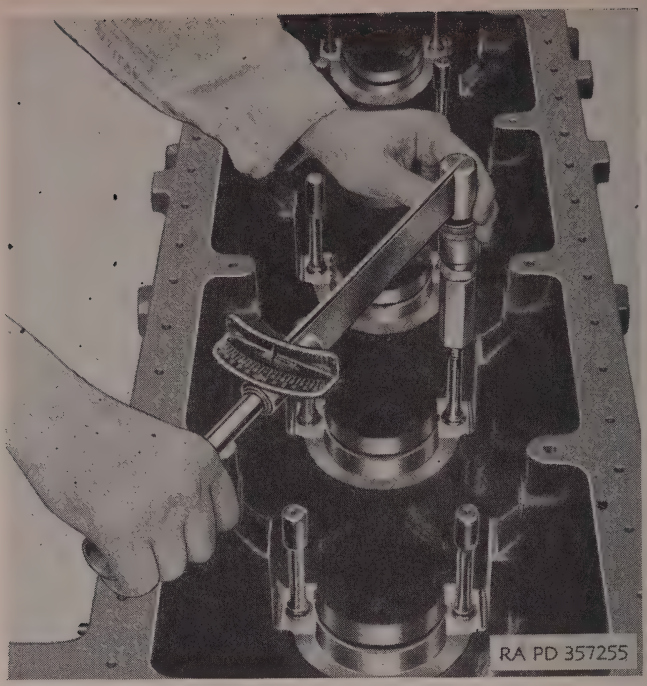


Figure 53. Torque-tightening main bearing studs.

These inserts are screwed into the softer casting until they are slightly below the surface. When the insert is set, a lock ring, broached to fit the splined end of the insert and coarse-milled on its outer edge, is driven into a counterbore. This lock ring prevents any turning of the threaded insert.

(*b*) To remove an insert, drill out the center with a drill slightly smaller than inner serrations, to the depth of the lock ring.

(*c*) Back out the insert with an "easy out." The insert will push the lock ring out.

(*d*) "Rosan" wrenches and drivers (fig. 4) are supplied to install inserts. These are short hexagonal pieces having an internal spline to fit the insert. Select the proper size and turn insert into casting, slightly below the surface. Place a new lock ring in position and center it over the insert with the correct driver. Drive the lock ring into the casting slightly below the surface.

61. Assembly of Crankcase (fig. 52)

If the rocker box oil drain line adapters (C) and breather elbow have been removed, reinstall them. Reinstall the pipe plugs and

sending units in oil passages opposite main bearings and the plug (UU) in end of main oil gallery at flywheel end. The oil pressure gage sending unit is installed opposite No. 3 main bearing. The low oil pressure light sending unit is installed opposite No. 4 main bearing.

Section X. REBUILD OF CRANKSHAFT AND CONNECTING ROD ASSEMBLIES

62. Disassembly of Crankshaft

a. Remove nuts from connecting rod bolts, loosen the caps, and pull rods from crankshaft. Tap the caps with a soft hammer, if necessary to loosen, but do not strike near the parting lines. Do not drop bearings; they are damaged easily. Reassemble rods when removed, as the parts must be kept together and installed in original positions.

b. Remove transmission shaft pilot ball bearing (NN) (fig. 52) from the flywheel end. Remove snap ring and "O" ring gasket from the flywheel end plug and withdraw plug.

63. Cleaning, Inspection, and Repair of Crankshaft Assembly

a. Cleaning. Clean all parts thoroughly with dry-cleaning solvent or volatile mineral spirits paint thinner. Flush out the oil passages from journals to crankpins.

b. Inspection.

(1) *Crankshaft.*

(*a*) The crankshaft and vibration damper are considered as one unit and are stocked as such. Neither shaft nor damper may be replaced separately.

1. Examine the pins and bores in counterweights carefully for cracks, scoring, or out-of-round (figs. 27 and 54). If a damaged part is found, all pins and weights must be replaced. The weights of these parts are matched accurately at assembly, and the critical balance might be destroyed by the substitution of unmatched parts.

2. Inspect damper hub carefully. If any cracks are evident, or if the pin bores show any signs of scoring or out-of-round condition, replace crankshaft and damper as an assembly.

3. Remove locking wire and check damper hub bolts to 1,000 inch-pounds torque. Replace locking wire.

(*b*) Examine crankshaft carefully for any signs of scuffing or overheating. Such signs are an indication of a defective bearing. Check the bearing again (par. 60*b*(4)).

(*c*) If magnaflux equipment is available, the crankshaft should be inspected by this method. If magnaflux is not available,

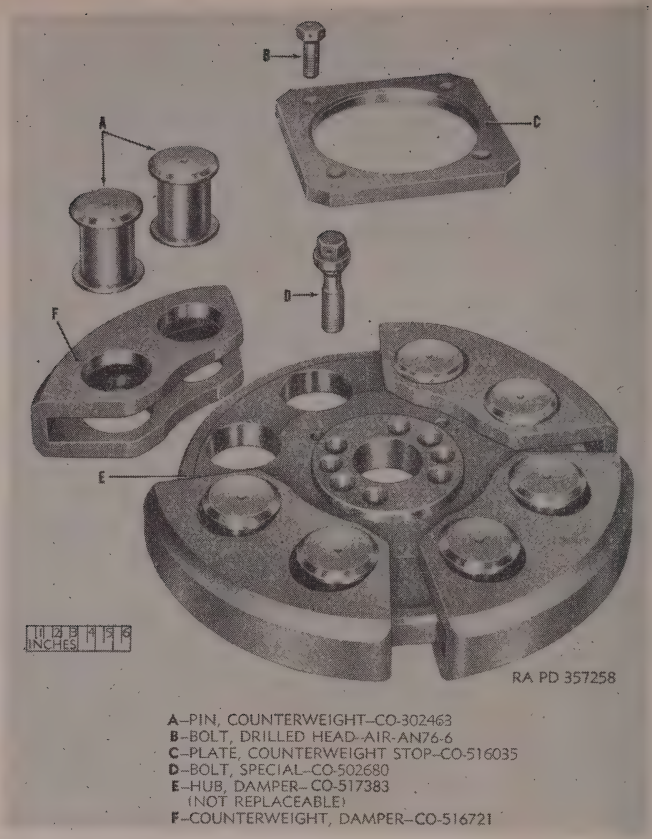


Figure 54. Vibration damper—exploded view.

the crankshaft should be inspected carefully with a magnifying glass for cracks, particularly in the areas around the oil tube holes and fillets adjacent to the cheeks. If cracks are discovered, crankshaft must be replaced.

(*d*) Check journal and crankpin diameters, and the crankshaft run-out to the limits specified in serviceability standards, (par. 123). To check run-out, support crankshaft by the end journals and check with dial indicator. Regrinding of crankshafts is not permitted. Shafts requiring such reconditioning must be replaced.

(2) *Connecting rods* (fig. 55).

(*a*) Check the rods for twist and bend. Make this check carefully as very close limits are specified in serviceability standards (par. 121). Do not attempt to straighten a bent rod; replace with a new rod.

(*b*) Clean any carbon deposit from piston pin bore with crocus cloth. Examine bore for scoring or cracks and check

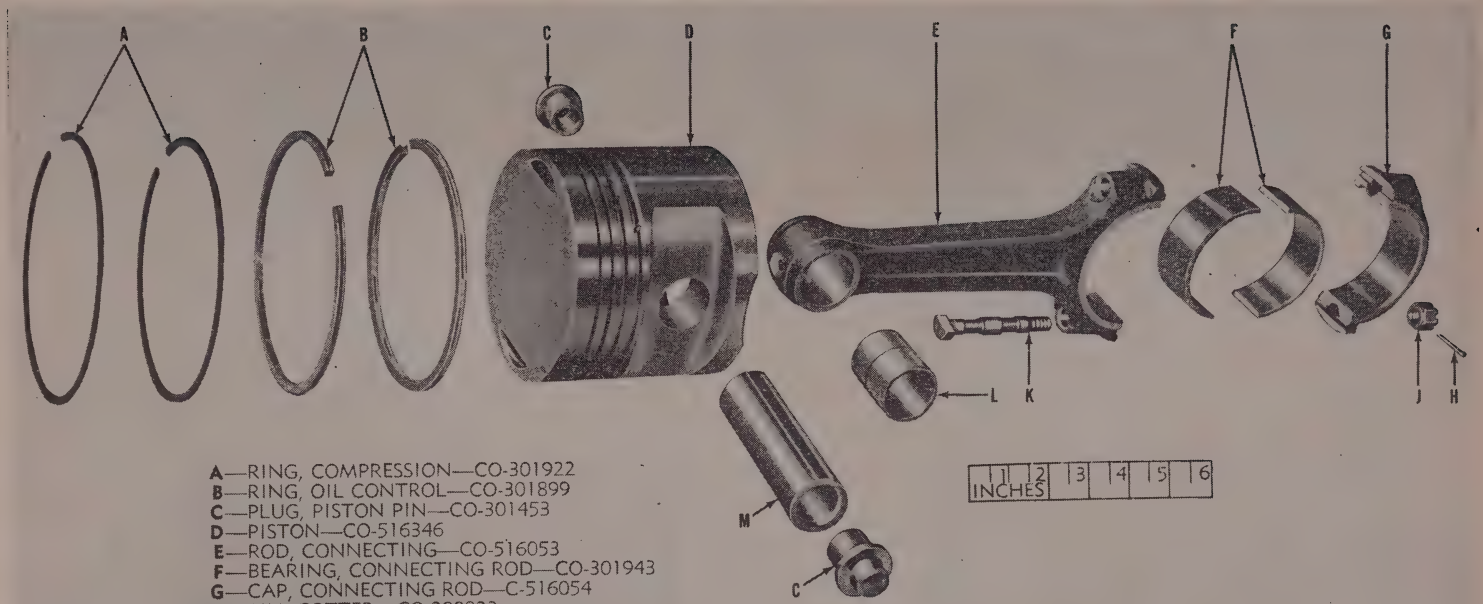


Figure 55. Connecting rod and piston—exploded view.

piston pin fit to limits specified in serviceability standard (par. 135).

(*c*) Check connecting rod bearings, both as to surface condition and for wear. (Refer to par. 60*b*(4).) Check thickness to limits specified (par. 121). Be sure that oil holes are clean and that identification markings are preserved. Renew markings with a grease pencil, if necessary. Never use a scriber or sharp tool to mark bearings.

(*d*) Check connecting rod bolts very carefully. These bolts are highly stressed in service and should be examined for any evidence of galling on the pilot diameter near the center of the bolt, and stretching, cracks, or scratches on any portion of the bolt. Light scratches may serve as a start for a fatigue crack. Discard all bolts about which there is the slightest doubt.

c. Repair.

(1) *Crankshaft.*

(*a*) Examine journals and crankpins, and polish out any fine scratches with crocus cloth and dry-cleaning solvent or volatile mineral spirits paint thinner.

(*b*) Look for any indications of scratches or scuffing on the crank cheeks. Scratches of any kind are dangerous and may be the cause of a later failure. It is important that they be removed or that the shaft be replaced.

(*c*) Examine the dowel pins in the flywheel end. Dowel pins must be tight. Oversize dowel pins are available for replacement (par. 78).

(2) *Connecting rods.*

(*a*) Damaged piston pin bearings are replaceable. Press out damaged bearing. To install new bearing, heat the rod end to 350° F., shrink bearing with dry ice, and press in place. Bore and ream to limits specified in serviceability standards (par. 121).

(*b*) If new bearings are being installed, they must be pinch-checked (fig. 56). Hold rod in a vise with soft jaws. Install new bearing halves in rod and cap, assemble bolts and pull up evenly, but do not tighten. Insert a 0.001-inch feeler gage in joint between rod and cap. Tighten bolt on the opposite side to 800 inch-pounds torque. Next, tighten the other bolt with a torque wrench until it begins to pinch feeler gage. The torque at this point should be between 250 and 550 inch-pounds. If torque required is not within these limits, install another bearing and repeat test.

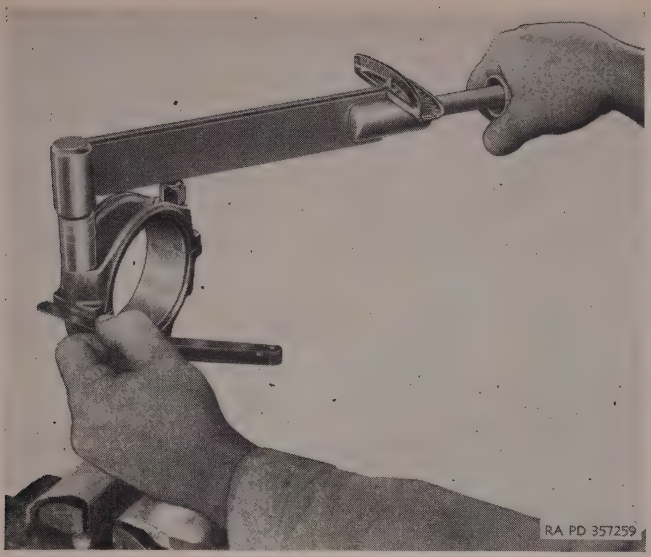


Figure 56. Pinch-check of connecting rod bearings.

64. Assembly of Crankshaft and Connecting Rods

a. Assemble connecting rods and bearings to the crankshaft. Lubricate bearings and crankpins with engine oil at assembly. Insert connecting rod bolts from the rod side, and see that the winged bolt heads are seated in the recesses provided. The torque range on these bolts is 750–850 inch-pounds. This range is provided to permit alinement of the slotted nut and bolt to permit insertion of a cotter pin. Run bolts down evenly and tighten to 750 inch-pounds torque. Examine for cotter pin alinement and tighten nuts further until alinement is obtained. Insert cotter pin. When both rods are assembled to each crankpin, check the side clearance (fig. 57) to the limits in serviceability standards (par. 121).

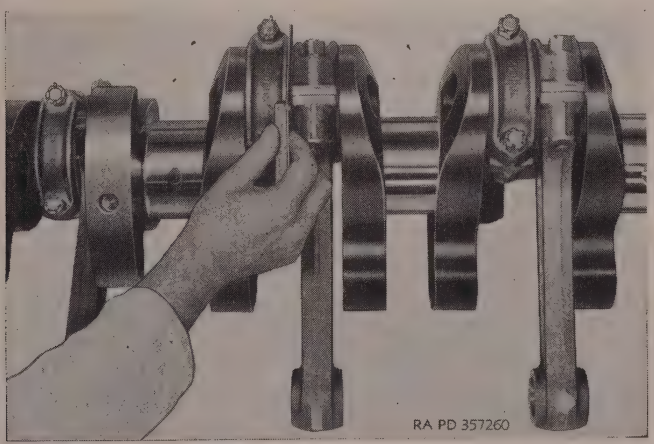


Figure 57. Checking side clearance of connecting rods.

b. Install a new "O" ring gasket (JJ) on the crankshaft plug (HH) (fig. 52). Install plug in the flywheel end of the crankshaft. Insert snap ring (KK) in the recess provided, using pliers (41–P–1992–35). Install transmission shaft pilot ball bearing in the crankshaft flange.

Section XI. REBUILD OF OIL FILTER AND HOUSING ASSEMBLY

65. Disassembly of Oil Filter and Housing Assembly (fig. 58)

a. Disassembly of Filter.

(1) Remove nuts holding filter head to housing and withdraw filter assembly.

(2) Break locking wire, remove retainer bolt from head, and separate filter from head.

(3) Remove filter pack retaining nut and slide individual filter packs and spacers from center tube.

b. Disassembly of Filter Housing (fig. 58).

(1) Remove pipe plugs and magnetic drain plug (A) from housing.

(2) Remove oil cooler by-pass valve by unscrewing valve housing from filter housing and discard gasket.

c. Disassembly of Oil Cooler By-Pass Valve (fig. 58).

(1) Remove cap (L) from valve housing (K) and discard gasket.

(2) Compress valve spring until cotter pin, through valve stem, can be removed, and separate the parts.

66. Cleaning, Inspection, and Repair of Oil Filter and Housing Assembly

a. Cleaning. Wash all parts in dry-cleaning solvent or volatile mineral spirits paint thinner. Be sure that the inner passages in the housing are free of sludge deposits. Clean all metallic particles from the magnetic plug. Wash individual filter packs carefully. Lint or heavy dirt deposits may be removed with a soft bristle brush. Caked carbon deposits which resist dry-cleaning solvent may be removed with carbon-remover solvent.

b. Inspection.

(1) Inspect filter housing for cracks. Inspect studs and replace as necessary (par. 46*b*(2)).

(2) Inspect each filter pack carefully. If the fine screen material is punctured, torn or broken, discard filter pack.

(3) Inspect the oil cooler by-pass valve spring (H), (fig. 58) for evidence of failure or distortion. Check spring compression to limits in serviceability standards (par. 133). See that the stem of valve (F) moves freely in housing (K).

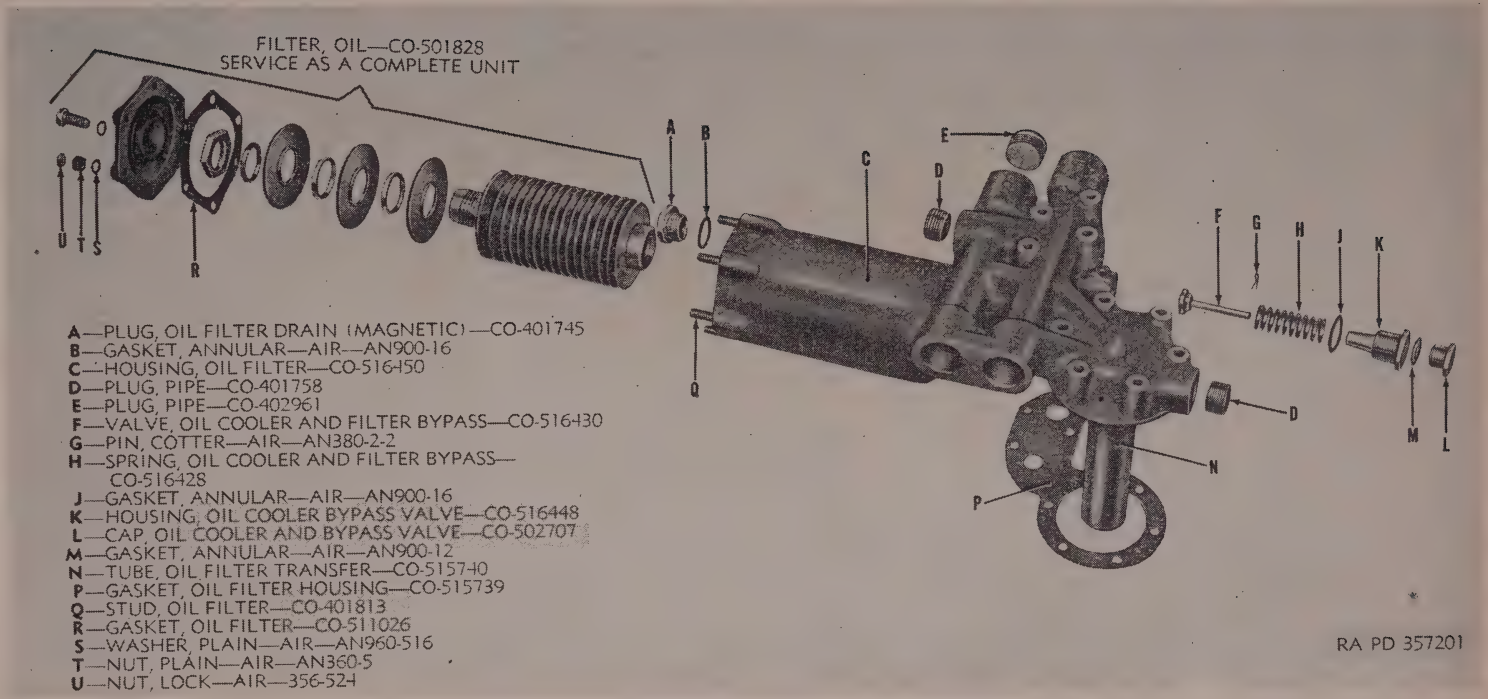


Figure 58. Oil filter and housing—exploded view.

67. Assembly of Oil Filter and Housing Assembly (fig. 58)

a. Oil Filter. Place a filter pack on center tube, then a spacer. Proceed alternately with packs and spacers until all have been assembled. Install pack retainer nut and tighten until the assembly cannot be turned on center tube. Place filter head on center tube, install retainer bolt, and secure with locking wire.

b. Filter Housing.

(1) Reassemble oil cooler by-pass valve, spring, and housing. Compress valve until the cotter pin can be inserted through valve stem and secured. Install the cap with new gasket, and tighten. Using a new gasket, install valve assembly in the filter housing.

(2) Replace all pipe plugs. Be sure that the four in-and-out oil passages are plugged. Install magnetic plug with new gasket.

(3) Place new gasket on filter head, and insert filter assembly in the housing. Use care not to damage filter packs. Secure filter with plain washers, nuts, and lock nuts.

Section XII. REBUILD OF THROTTLE LINKAGE

68. Disassembly of Throttle Linkage (fig. 59)

a. General. Ordinarily, complete disassembly of throttle linkage is not necessary at overhaul. The inspections listed below should be made to determine serviceability of the assembled linkage.

(1) Detach the two carburetor control rods (A and CC) and the two governor control rods (N and T) from the levers. Check the swivel in the rod end bearings (D, L, and Q) to see that they move freely. Discard any having tight or frozen swivels.

(2) Lubricate the two needle bearings (GG) through the grease fittings provided.

(3) Rotate cross shaft tube and cross shaft (Y and PP) and note whether any bending or rough spots occur during rotation. If none occur, throttle linkage is satisfactory for use without disassembly.

(4) Examine all levers and rods for cracks or breaks, replacing any defective parts.

b. Disassembly (fig. 59). If any defects are detected, the linkage may be disassembled to replace the unsatisfactory part in the manner stated below.

(1) Adjustable end bearings (DD) are removed by loosening check nuts and turning out bearings. Note that rod ends

are threaded differently, one with right-hand and the other with left-hand threads.

(2) Loosen clamp bolts (R) and remove end levers (K) from cross shaft. Remove Woodruff keys.

(3) Slide cross shaft tube (Y), together with right camshaft gear housing cover (LL) off the cross shaft.

(4) Loosen clamp bolt and remove cross shaft tube to governor lever (U). Remove the flat key.

(5) Remove oil seals (FF) and needle bearings (GG) from the cross tube levers.

(6) Remove internal snap rings in the camshaft gear housing cover with pliers (41–P–1992–35). Remove external snap ring from end of cross shaft tube with pliers (41–P–1992–27). Disengage inner snap ring from bearing inner race and press housing cover and bearing off tube.

(7) Loosen clamp bolt and remove cross shaft to governor lever (K) and remove Woodruff key. Disengage external snap rings and press ball bearing (F) and center bearing housing (S) from shaft. Remove internal snap rings from housing and push out bearing.

69. Cleaning, Inspection, and Repair of Throttle Linkage

a. Cleaning.

(1) Clean outer surfaces of ball bearings with a cloth dampened with dry-cleaning solvent or volatile mineral spirits paint thinner. These are sealed bearings and should not be dipped in solvent.

(2) Wash all other parts in dry-cleaning solvent.

b. Inspection.

(1) Check cross shaft tube and cross shaft for bends. See that cross shaft rotates freely in the tube. Check all rods for bends and damaged threads. Check levers for cracks.

(2) See that ball bearings rotate freely. Check needle bearings for freedom of rotation. Check swivel joints in rod end bearings; they must move freely.

c. Repair. Straighten bent rods and shafts. Replace all parts which cannot be reconditioned.

70. Assembly of Throttle Linkage (fig. 59)

a. Cross Shaft Tube.

(1) Insert needle bearing (GG) and bearing oil seal (FF) in lever end of cross shaft tube. See that the lubricating fitting is installed in tube. Install the pin, washer, nut, and cotter pins in the lever.

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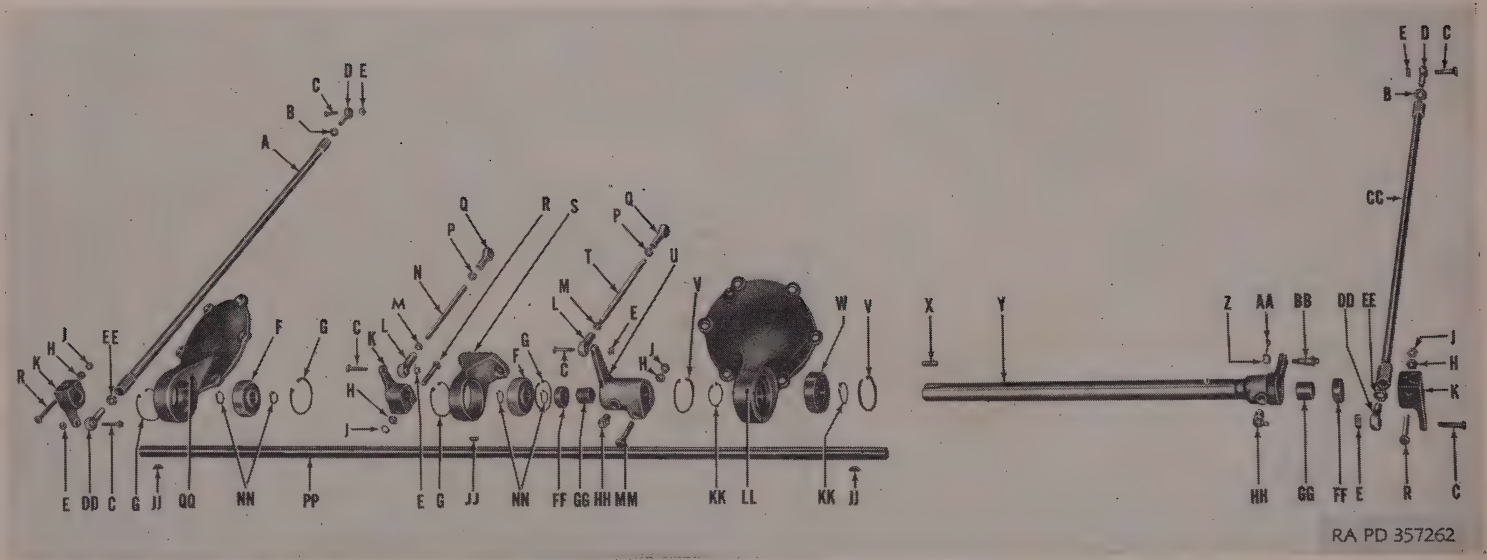


Figure 59. Throttle linkage—exploded view.

A—ROD, CARBURETOR CONTROL, LH—CO–502604
B—NUT, CHECK—AIR–AN316–6R
C—BOLT, HEX-HEAD—AIR–AN3–C10A
D—BEARING, ROD END, RH THREAD—CO–502130
E—NUT, SELF-LOCKING—AIR–AN365–1032
F—BEARING, BALL—CO–502626
G—RING, SNAP, INTERNAL—CO–502020
H—NUT, PLAIN ENGINE—AIR–AN360–4
J—NUT, LOCK—AIR–356–428
K—LEVER, CROSS SHAFT TO GOVERNOR—CO 515373
L—BEARING, ROD END, LH THREAD—CO–502093
M—NUT, CHECK—AIR–AN316–4L
N—ROD, GOVERNOR CONTROL—CO–502623
P—NUT, CHECK—AIR–AN316–4R
Q—BEARING, ROD END, RH THREAD—CO–502092
R—BOLT, HEX-HEAD—AIR–AN4–13A
S—HOUSING, CENTER BEARING—CO–515375
T—ROD, GOVERNOR CONTROL—CO–502622
U—LEVER, CROSS SHAFT TUBE TO GOVERNOR—CO–515377
V—RING, SNAP, INTERNAL—CO–502139
W—BEARING, BALL—CO–502646
X—KEY, FLAT—CO–502084
Y—TUBE, CROSS SHAFT—CO–301956
Z—NUT, SLOTTED, ENGINE—AIR–AN355–4
AA—PIN, COTTER—AIR–AN380–2–3
BB—PIN, CONTROL LEVER—CO–302325
CC—ROD, CARBURETOR CONTROL—CO–502602
DD—BEARING, ADJUSTABLE, LH THREAD—CO–502129
EE—NUT, CHECK—AIR–AN316–6L
FF—SEAL, OIL—CO–502083
GG—BEARING, NEEDLE—CO–502091
HH—FITTING, LUBRICATING—AIR–AN286–4
JJ—KEY, WOODRUFF—AIR–AN280–405
KK—RING, SNAP—CO–502101
LL—COVER, CAMSHAFT GEAR HOUSING, RH—CO–515848
MM—BOLT, HEX-HEAD—AIR–AN4–15A
NN—RING, SNAP—CO–502102
PP—SHAFT, CROSS—CO–515953
QQ—COVER, CAMSHAFT HOUSING, LH — CO–515847

Figure 59.—Continued.

(2) Install an external snap ring in groove closest to the lever end of the tube with pliers (41–P–1992–27). Install cross shaft tube ball bearing (W) against external snap ring. Secure bearing in position with another external snap ring.

(3) Slip right camshaft gear housing cover (LL) over bearing and secure with internal snap rings, using pliers (41–P–1992–35).

(4) Install Woodruff key and lever (U) on end of cross shaft tube. Clamp lever with bolt, plain nut, and lock nut.

(5) Install needle bearing (GG), seal (FF), and lubricating fitting (HH) in lever.

b. Cross Shaft.

(1) Install cross shaft center bearing (F) with two external snap rings (NN), using pliers (41–P–1992–27). Slide center bearing housing (S) over bearing and secure with two internal snap rings (G), using pliers (41–P–1992–35).

(2) Position cross shaft to governor lever (K) over Woodruff key, and clamp with bolt, plain nuts, and lock nut.

(3) Put a cross shaft bearing internal snap ring over the left end of the cross shaft. Install an external snap ring in its groove, slip on left cross shaft ball bearing (F) and position it with a duplicate external snap ring. Slip left camshaft gear housing cover (QQ) over bearing and position with internal snap ring (G) already on the shaft, and install a duplicate ring on the opposite side.

(4) Install left cross shaft lever (K) over Woodruff key and clamp with bolt, plain nut, and lock nut.

(5) Slide right-hand end of cross shaft through cross shaft tube. Install right end cross shaft lever (K) over Woodruff key and clamp with bolt, plain nut, and lock nut.

(6) Assemble lever to governor rods with right- and left-hand threaded check nuts and adjustable rod end bearings. Fasten longer rod (T) to the tube lever (U) and shorter rod (N) to cross shaft lever, using bolts and self-locking nuts.

(7) Assemble cross shaft lever to carburetor control rods with check nuts and adjustable rod end bearings. One right-hand and one left-hand threaded check nut and rod end bearing are used with each rod. Fasten longer rod to left lever, and shorter rod to right lever, using bolts and self-locking nuts.

(8) Lubricate needle bearings through lubricating fittings, as specified on lubrication order in operator's manual.

Section XIII. REBUILD OF PISTONS, PINS, AND RINGS

71. Disassembly of Piston

a. Check all piston rings before removal and mark any sticking ring so that a detailed inspection can be made later.

b. Remove rings with remover and replacer (41–R–2378–570) (fig. 62). Tag rings so that serviceable rings may be installed in their original grooves (fig. 55).

72. Cleaning, Inspection, and Repair of Pistons, Pins, and Rings

a. Cleaning.

(1) Clean the pistons and rings with carbon-remover solvent. Scrape off remaining deposits. A broken piston ring makes a good scraper to remove deposits from ring grooves. Care should be taken not to scratch or gouge rings or ring lands when scraping off deposits. Be certain that oil drain holes in oil rings and in third and fourth ring grooves are clean. Carbon can be removed with an undersize drill.

(2) Clean carbon deposits from piston pins and from piston pin bores with crocus cloth wet with dry-cleaning solvent or volatile mineral spirits paint thinner.

b. Inspection.

(1) Examine piston pins for nicks, scratches, and abrasions. Reject any pins having defects of this nature.

(2) Inspect piston pin plugs. Nicks or scratches on ends or cracks in any part of plug are cause for rejection. Also reject any plugs that are worn to the point where they no longer will position the piston pin centrally.

(3) Inspect piston ring wear surfaces. Reject any rings that are scuffed, scored, chipped, or scratched, or have abrasions elsewhere on ring.

(4) Carefully examine entire piston for cracks and flaws, paying particular attention to ring lands in which rings were stuck. Small cracks will be evident, under strong light, as irregular dark streaks. Replace any cracked pistons.

(5) Check piston ring gaps with ring gage and compressor (41–G–534–50). Place rings in small diameter of tool and check gap (fig. 60.) Check ring side clearance in grooves (fig. 61). Check pistons and piston pins. All measurements must be within limits specified in serviceability standards (par. 136).

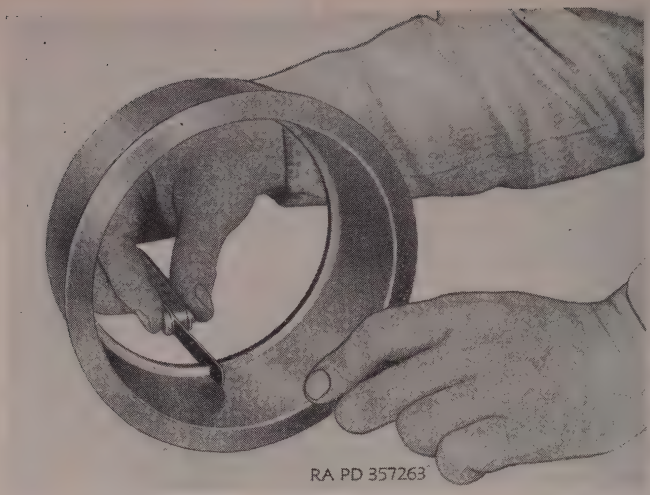


Figure 60. Measuring piston ring gap, using gage and compressor (41–G–534–50).

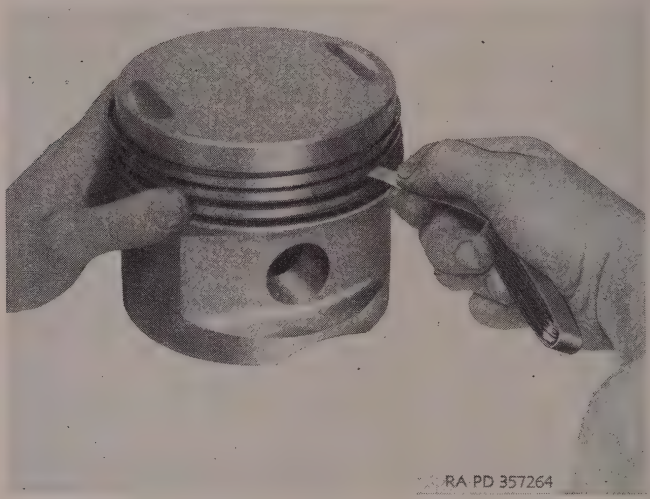


Figure 61. Measuring piston ring side clearance.

c. Repair.

(1) Rejection of a piston for scores and scratches is a matter of judgment. Metal raised by minor scores and scratches may be removed by use of a fine mill file.

(2) Piston rings cannot be repaired. Unserviceable rings must be replaced.

(3) Pistons are marked, at original engine assembly, on the bottom edge of skirt, showing exhaust side of piston and the cylinder number. Replacement pistons must be marked similarly.

73. Assembly of Pistons, Pins, and Rings

a. Using new rings as required, install piston rings in their original positions with replacer (41–R–2378–570) (fig. 62).

b. Assemble piston pins and dome plugs in pistons.

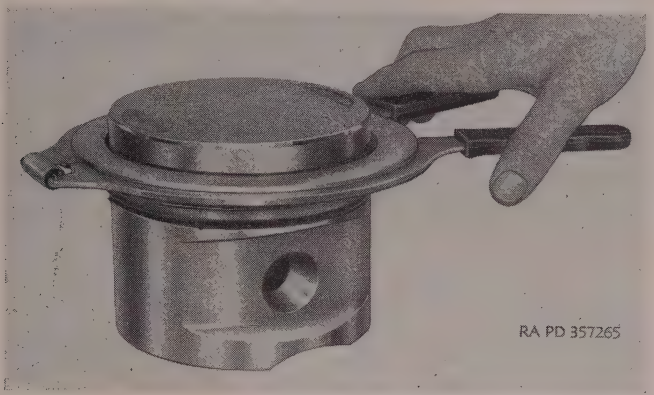


Figure 62. Installing piston ring with remover and replacer (41–R–2378–570).

Section XIV. CLEANING, INSPECTION, AND REPAIR OF INDIVIDUAL PARTS

74. Oil Pressure Control Valve (fig. 63)

a. Disassembly.

(1) Remove the housing cap (H), discard gasket, and pull spring and spring seat (E) from housing.

(2) Unscrew valve seat (B) from housing and remove valve (C).

b. Cleaning. Clean all parts in dry-cleaning solvent or volatile mineral spirits paint thinner.

c. Inspection. Inspect the parts to the limits specified in serviceability standards (par. 132).

d. Repair. This valve is serviced only as a complete unit.

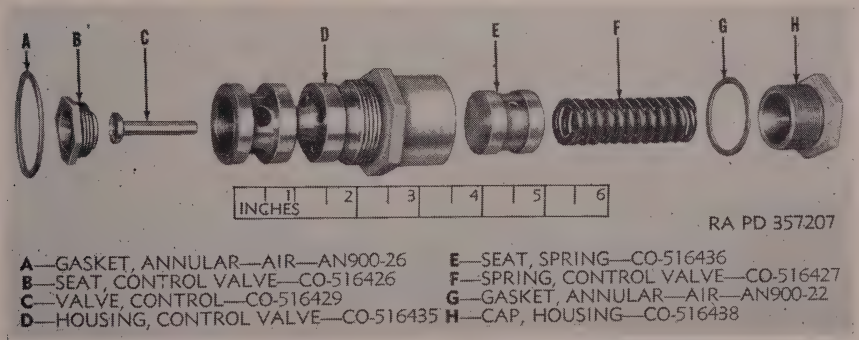


Figure 63. Oil pressure control valve—exploded view.

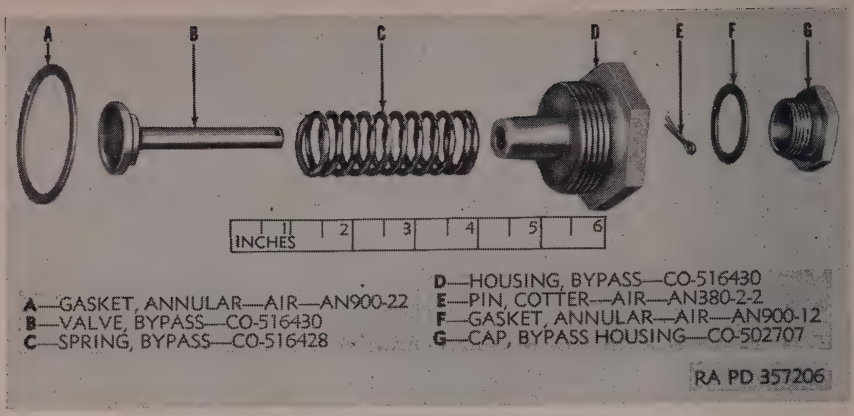


Figure 64. Oil filter by-pass valve—exploded view.

e. Reassembly.

(1) Insert valve (C) in valve housing, install valve seat (B), and tighten securely.

(2) Place spring seat (E) in housing, insert valve spring, and install housing cap with a new gasket. Secure cap to housing with locking wire. Adjustment of this valve usually is made at engine test. The pressure at which the valve opens may be raised by addition of special washers in cap over the spring.

75. Oil Filter By-Pass Valve (fig. 64)

a. Disassembly. Remove cap (G) from housing and discard gasket. Compress valve until cotter pin can be removed from the valve stem.

b. Cleaning. Clean all parts in dry-cleaning solvent or volatile mineral spirits paint thinner.

c. Inspection. Inspect the parts to limits specified in serviceability standards (par. 133).

d. Reassembly. Place valve spring on housing (D), insert valve, and compress until cotter pin can be secured through the valve stem. Install housing cap with new gasket. Secure cap to housing with locking wire.

76. Oil Pan (fig. 52)

a. Cleaning. Clean pan thoroughly with dry-cleaning solvent or volatile mineral spirits paint thinner. Clean sump screens and sump housings with solvent. These parts are removed at engine disassembly (par. 38).

b. Inspection.

(1) With the aid of a strong light (or a better method, if avail-

able), examine oil pan for cracks. Any cracks are cause for rejection.

(2) Examine the flange carefully. Local discoloration of the finished surface is evidence of oil leakage.

(3) Examine oil sump screens and discard, if torn or broken.

c. Repair.

(1) Replace defective studs (par. 46*b*(2)).

(2) Remove any raised metal at dents or scratches with a fine mill file.

77. Flywheel Group (fig. 26)

a. Cleaning. Clean the parts with dry-cleaning solvent or volatile mineral spirits paint thinner.

b. Inspection.

(1) Inspect friction discs, pressure plate, and damper spacer plate for imperfections or signs of failure. There are no definite limits established for these parts and good judgment must decide if parts are to be replaced. Examine torsion damper spring and replace, if cracks are evident, or if a permanent set or distortion is noticed.

(2) Inspect drive springs for cracks or breaks. When these springs are assembled with their seats, they should fit snugly in the flywheel recesses. Any looseness is indication of a defective spring. Replace it and test other springs as specified in serviceability standards (par. 127).

(3) Check fit of crankshaft to flywheel dowel pins in the holes of flywheel hub. If any looseness is evident or if inspection of the crankshaft indicates the need for oversize dowel pins, the replacement operations should be performed at the same time.

78. Flywheel Repair

a. Oversize Dowel Pins.

(1) The dowel pins are secured in the crankshaft flange by small set screws in the outer surface of crankshaft flange. Loosen these set screws and extract dowel pins.

(2) Two sizes of dowel pins are stocked for replacement, 0.0020 inch and 0.0030 inch oversize. Fixture set (41–F–2997–185) (fig. 6) is provided for dowel pin replacement.

b. Replacing Dowel Pins.

(1) Pilot the reaming fixture in the flywheel and bolt it in place. With the special double-end reamer, ream the flywheel holes for the dowel pin selected.

(2) With same fixture and reamer, repeat reaming operation on crankshaft flange.

(3) Drive new dowel pins in the crankshaft flange until the grooves in the pins line up exactly with set screw holes. Tighten set screws.

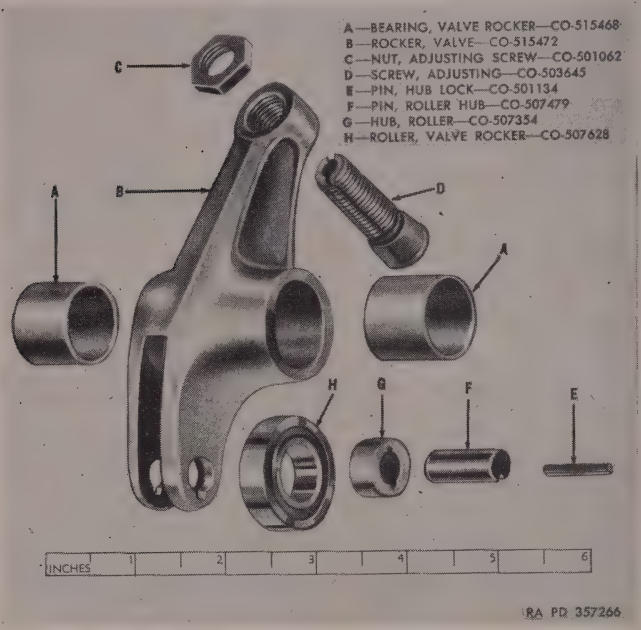


Figure 65. Valve rockers—exploded view.

79. Valve Rockers (fig. 65)

a. Cleaning. Clean assembled parts by washing in dry-cleaning solvent or volatile mineral spirits paint thinner.

b. Inspection.

(1) See that the adjusting screws (D) turn freely. Inspect the assembly for cracks. Inspect the rocker bearings. If loose or damaged, discard the entire rocker assembly. See that rocker roller turns freely and is free of scuff or score marks. Reject assembly for any of these reasons. See that oil tube is secure in each rocker support shaft.

(2) Inspect assemblies to serviceability standards (par. 140). Only clearance dimensions can be checked. The value rocker roller and hub clearance can be checked by mounting a dial indicator against the roller with the entire rocker assembly positioned securely. Move the roller to its extremes of travel. Total indicator reading is the clearance.

c. Repair.

(1) Polish minor scratches and scores from rocker support shafts with crocus cloth. Reject any shafts with loose oil tubes or heavy scoring.

(2) If adjusting screw does not turn freely, clean up any damaged threads. If threads cannot be cleaned up, replace screw. Defects in the rocker assembly are not repairable. Replace any defective assemblies.

80. Ignition Harness

a. Clean ignition harness with carbon tetrachloride. Pay particular attention to spark plug cable insulators and contacts.

Caution: Never use solvent or water for cleaning electrical parts. Solvent decomposes rubber and water may cause short circuits.

Warning: Fumes from carbon tetrachloride are extremely dangerous. Never use it in a closed room. Be sure that adequate ventilation is provided.

b. Inspect all harness cables and connections for looseness, burned or damaged condition, and frayed insulation or shielding. Repair any defects or replace the defective part. Spanner nuts on cable assemblies are removed with spanner wrench (41–W–3249–900).

c. Check all cables for electrical continuity. With a high tension ignition tester, test leads for electrical leakage. Replace any defective cables.

81. Intake Manifolds (fig. 66)

a. Disassembly. The intake manifolds are similar assemblies and are reversible on the engine. Each manifold consists of seven castings: two end elbows, two intermediate sections, one right center section, one left center section, which attach to the cylinders, and a hot-spot section. The intake hot-spot section is mounted on studs on the center section. The joint between right center and left center sections is made with an "O" ring gasket. The other sections are joined with short hose connections and secured with clamps. Loosen clamps and separate sections.

b. Cleaning. Wash metal parts with dry-cleaning solvent or volatile mineral spirits paint thinner and see that all carbon deposits are removed from inner surfaces. Clean hose connections with carbon tetrachloride. Remove Donaldson valves from left intake manifold hot-spot section and clean them.

c. Inspection. Inspect intake manifold castings for cracks and see that mounting flanges are smooth. Replace any connector hoses that show signs of cracking or deterioration. Replace damaged connector hose clamps.

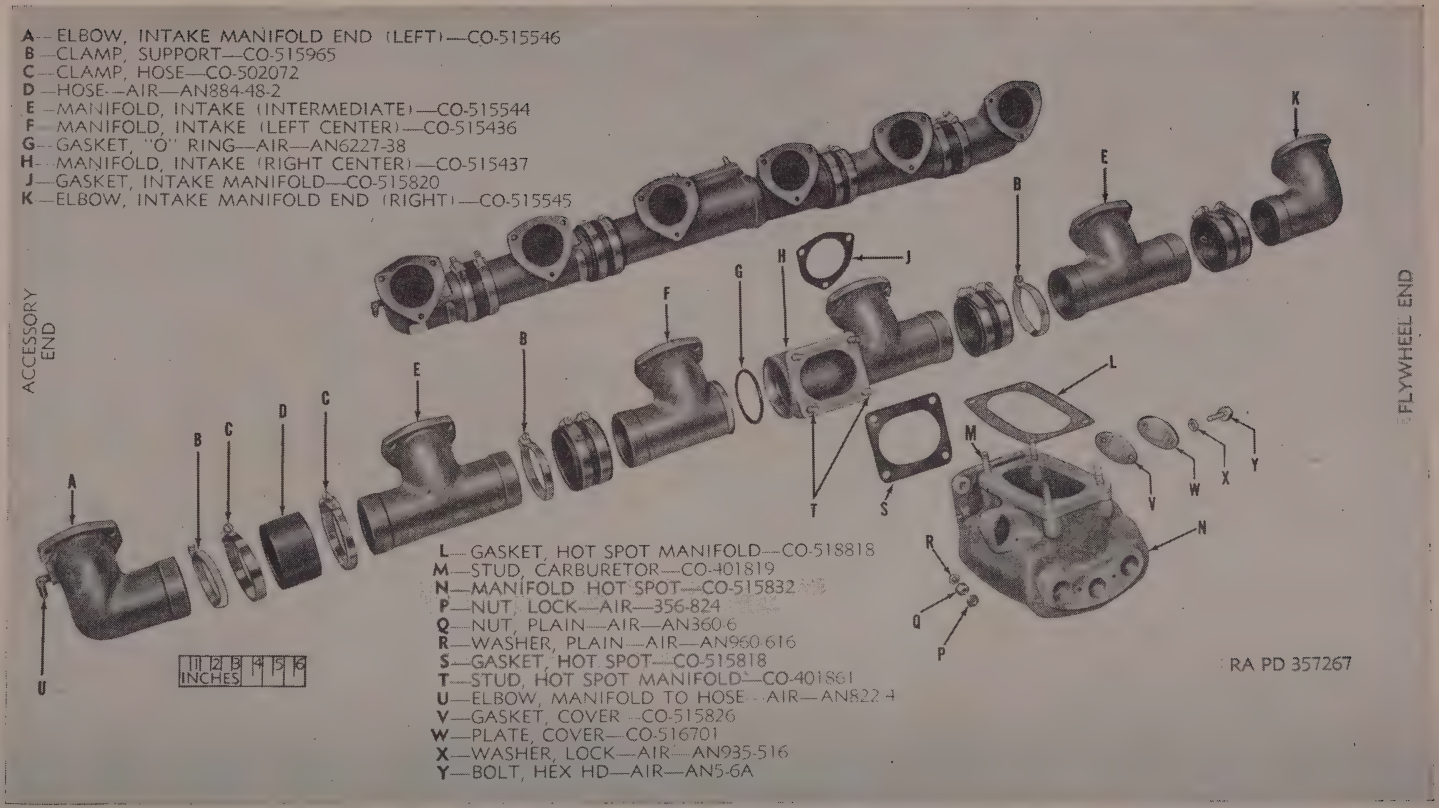


Figure 66. Intake manifold—exploded view.

d. Reassembly.

(1) Install new "O" ring gaskets on the two left center intake manifold sections. Push the right center intake manifold sections over the "O" ring gasket. See that pipe plugs are in right center sections.

(2) Install a serviceable hose at each end of these assemblies with two hose clamps per hose. Add the four intermediate intake manifold sections to the assembly, centering hose connections over joints between sections. Tighten hose clamps enough to prevent assembly from turning or falling apart.

(3) Install the four intermediate sections to end elbow hose connections, using two clamps per hose. Join end elbows to the assembly, again centering hoses and lightly tighten the clamps.

(4) See that tapped holes in flywheel end intake manifold sections are plugged.

(5) Provision is made for magneto ventilation through ventilating lines installed between the magneto and the accessory end intake manifold elbows. Note that the air passages must be restricted either in the tube fittings or the manifold elbows to No. 54 drill size.

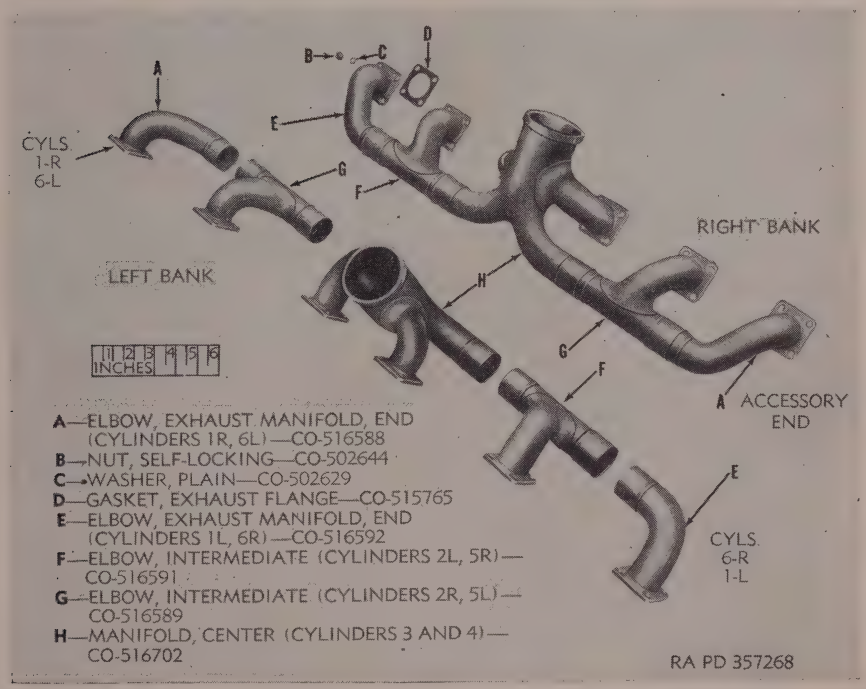


Figure 67. Exhaust manifold—exploded view.

82. Exhaust Manifolds (fig. 67)

a. Disassembly. The exhaust manifolds are similar assemblies and are reversible on the engine. Each manifold consists of five sections: two end elbows, two intermediate sections, and a center section. The sections are provided with slip joints and may be pulled apart as desired.

b. Cleaning. Wash the parts with dry-cleaning solvent or volatile mineral spirits paint thinner. See that all deposits are removed from the inner surfaces.

c. Inspection. Inspect all pieces for cracks, paying particular attention to areas surrounding welded joints. See that the inner walls are clean and free of deposits.

d. Repair. Weld minor cracks.

e. Reassembly. Slip intermediate elbows into center manifolds and then insert end elbows into intermediate elbows.

83. Engine Shrouds and Air Deflectors (figs. 14 and 16)

a. Inspect all shroud and baffle pieces for cracks and bends. Short, small cracks may be stopped by drilling a $\frac{3}{64}$-inch diameter hole at each end of the crack. Cracks more than $1\frac{1}{2}$ inches long should be repaired by welding. Any bent or warped pieces should be straightened or discarded.

b. Check all lock plates and replace as necessary.

c. Check intercylinder cover springs, pins, and fastenings for condition and satisfactory operation.

84. Vent and Fuel Lines

Inspect all hoses for leaks, cracks, and general deterioration. Particular care should be taken on spots that show evidence of chafing. Discard any leaking or damaged hoses.

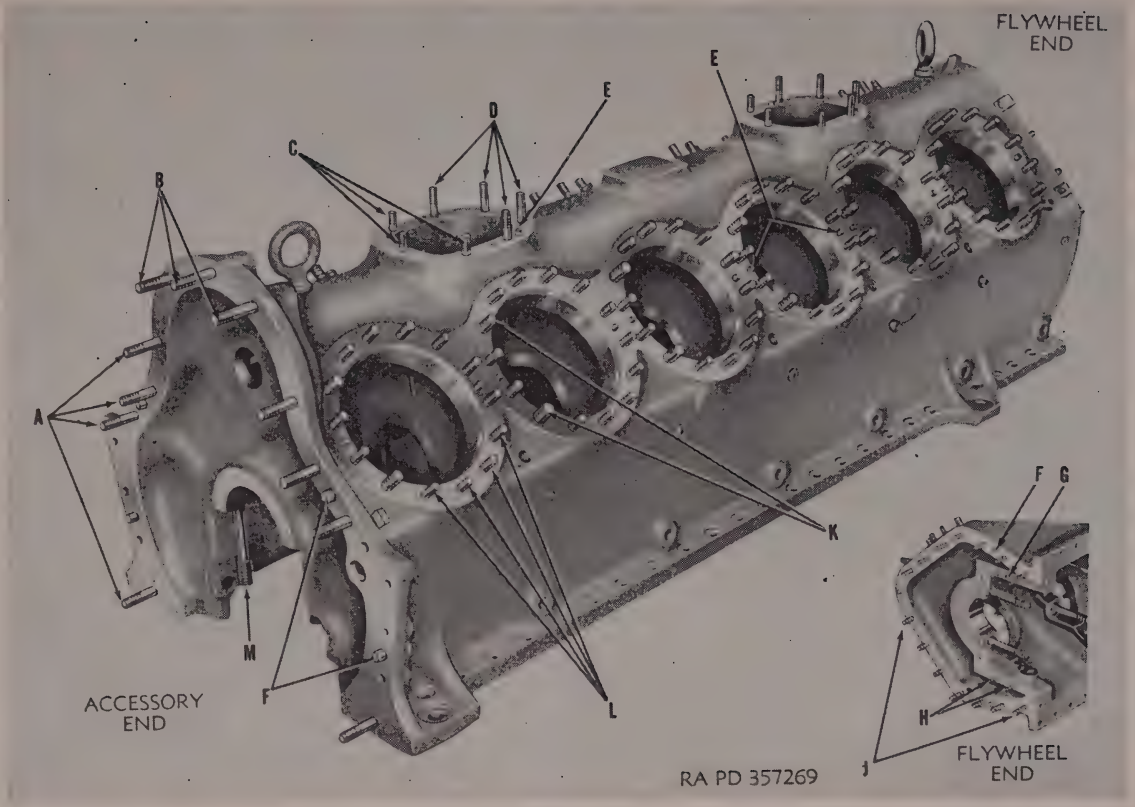


Figure 68. Crankcase studding.

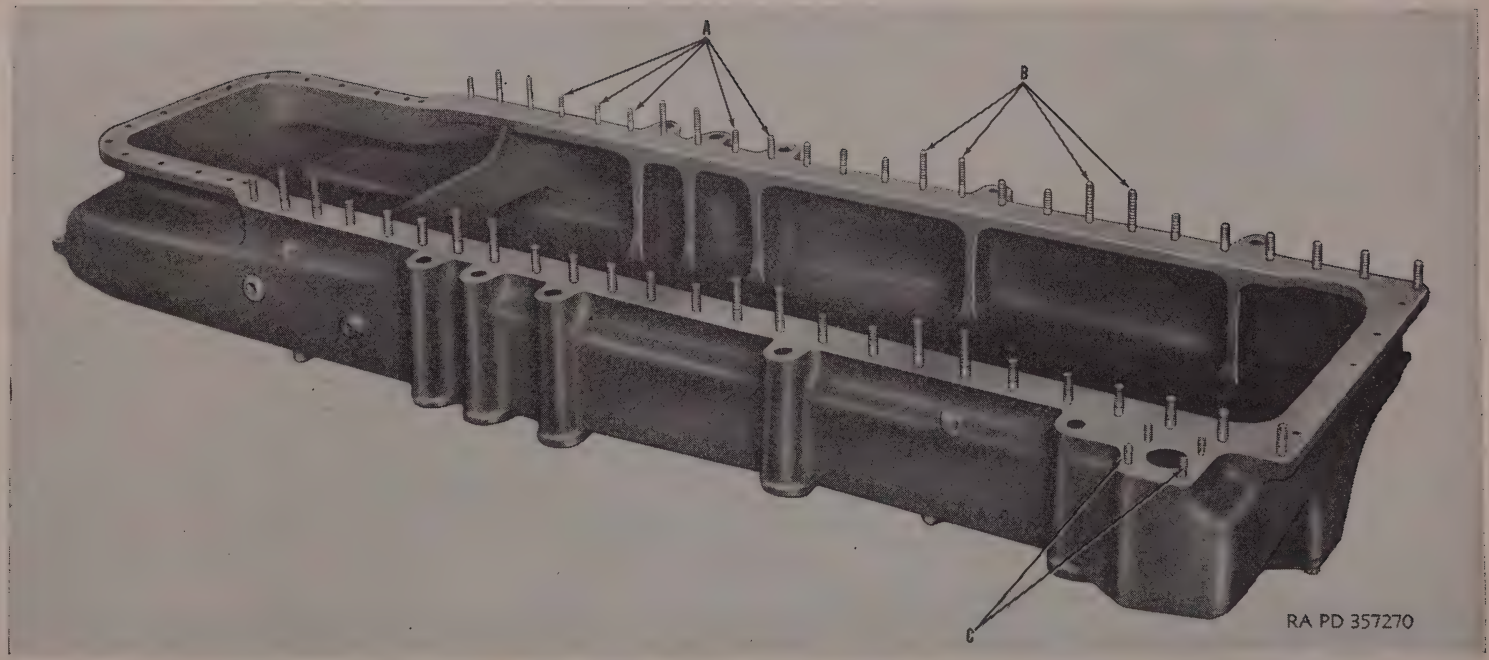


Figure 69. Oil pan studding.

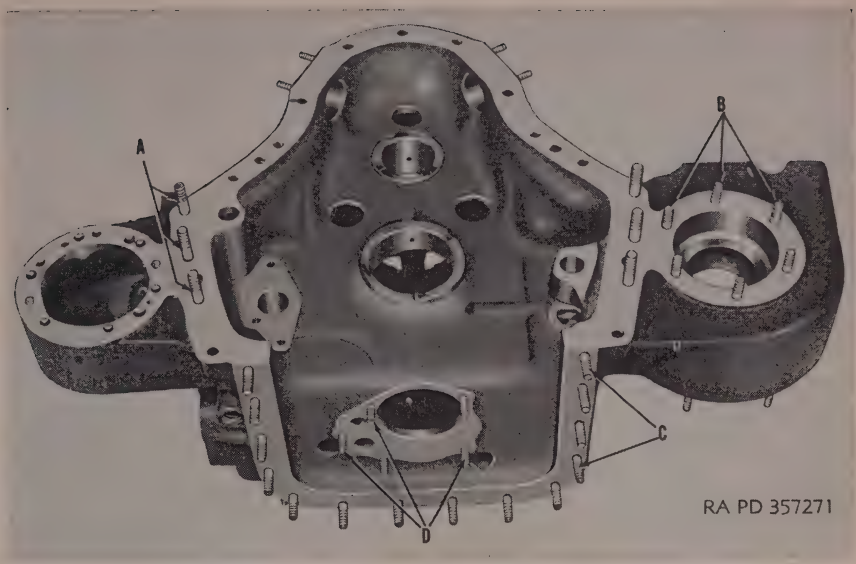


Figure 70. Accessory case studding—bottom.

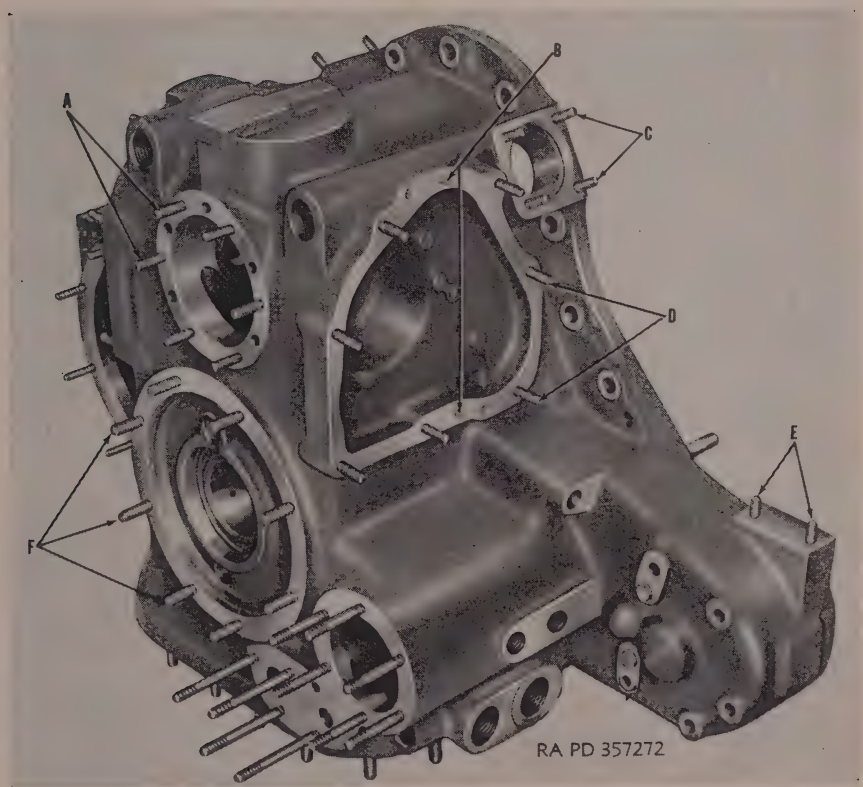


Figure 71. Accessory case studding—right-hand side.

85. Stud Data

Note that studs are threaded NC (national coarse) on one end and NF (national fine) on other. The NC end is threaded into the casting. Part numbers of oversize studs have the appropriate letter as a suffix to indicate the oversize.

Table II. Stud Identification

(Part No. suffix for 0.003-in. oversize, "H"; for 0.007-in. oversize, "S"; for 0.012-in. oversize, "J.")

Fig. No.	Ref.	Length (boss to end of stud)	No. reqd.	Mfrs. part No.	Fig. No.	Ref.	Length (boss to end of stud)	No. repd.	Mfrs. part No.
		(Inches)					*(Inches)*		
16	B	0. 66	12	CO–401823	69	B	1. 87	16	CO–401933
16	F	0. 97	36	CO–401813	69	C	0. 69	4	CO–401885
16	G	0. 94	48	CO–401861	70	A	1. 66	6	CO–401877
16	J	2. 64	48	CO–401872	70	B	1. 00	6	CO–401861
23	A	1. 09	4	CO–502468	70	C	1. 14	14	CO–401819
31	AL	3. 09	4	CO–401873	70	D	0. 83	5	CO–401812
31	LL	1. 00	6	CO–502468	71	A	0. 97	6	CO–401813
37	B	1. 00	4	CO–401812	71	C	0. 88	4	CO–401813
37	M	0. 75	4	CO–401808	71	D	1. 00	7	CO–401813
38	H	0. 75	4	CO–401812	71	E	0. 50	2	CO–401881
39	S	0. 72	4	CO–401811	71	F	1. 06	8	CO–401861
41	FF	0. 88	20	CO–401813	72	A	0. 50	2	CO–401881
44	N	0. 82	12	CO–401811	72	B	1. 00	6	CO–401813
44	BB	2. 03	6	CO–401883	72	D	0. 88	4	CO–401813
52	DD	1. 22	2	CO–515949	72	E	2. 06	5	CO–401883
52	EE	1. 22	2	CO–401876	72	F	3. 06	4	CO–401897
52	GG	1. 45	4	CO–401931	72	G	0. 72	2	CO–401811
58	Q	0. 88	6	CO–401813	72	H	1. 31	8	CO–401837
66	M	1. 14	8	CO–401819	72	J	2. 12	1	CO–401883
66	T	1. 03	8	CO–401861			DOWEL		
68	A	1. 66	8	CO–401877			PINS		
68	B	1. 88	3	CO–401878	16	H	0. 25	48	CO–501824
68	C	0. 88	6	CO–401861	52	RR	---------	3	CO–502097
68	D	1. 38	8	CO–401871	52	WW	1. 75	2	CO–502119
68	H	0. 88	4	CO–401811	68	E	0. 25	28	CO–501031
68	J	1. 22	16	CO–401876	68	F	0. 38	7	CO–501827
68	K	0. 94	24	CO–401880	68	G	0. 31	2	CO–501824
68	L	0. 94	144	CO–401879	71	B	0. 22	2	CO–501824
68	M	---------	14	CO–301087	72	C	0. 22	2	CO–501824
69	A	1. 14	34	CO–401819					

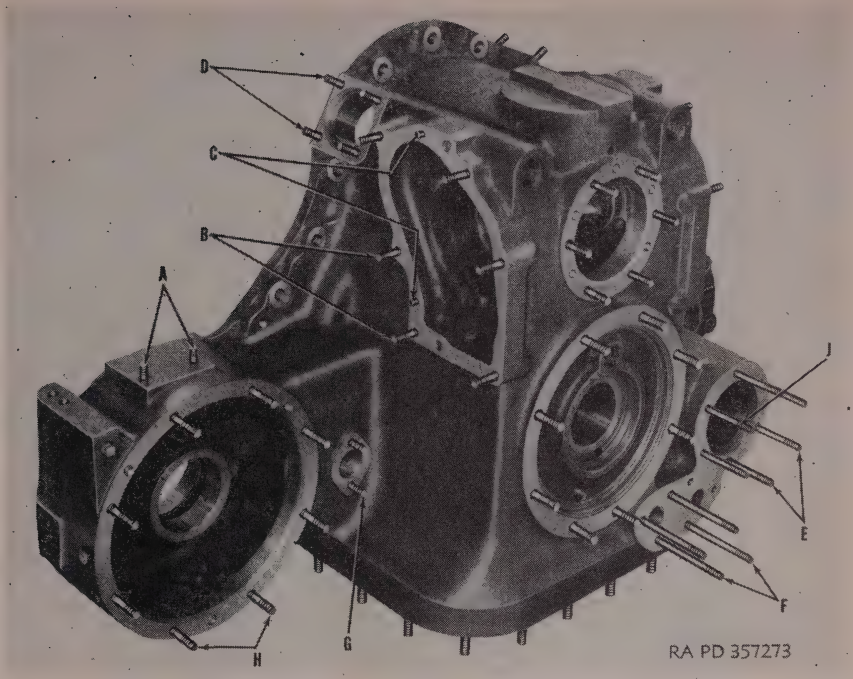


Figure 72. Accessory case studding—left-hand side.

Section XV. ASSEMBLY OF ENGINE FROM SUBASSEMBLIES

86. Torque Tightness

During engine assembly, numerous references are made to torque specifications. Torque wrenches with indicating scales are provided for tightening nuts to specified limits. Readings on these scales are worthless unless the wrenches are used properly. It should be understood that it is *not* the force required to turn the nut that is important, but that the resultant pull on the stud itself is the end desired. Therefore, resistance of the nut to turning must be reduced to a minimum. Threads must be undamaged and clean, and they must be lubricated with mica base antiseize compound to reduce unavoidable friction. When using a torque wrench, the final reading must be taken *while the nut is turning.* If the torque reading is close to that specified when the wrench is at the end of its swing, back off the nut slightly and change the wrench position, then pull to the desired reading while the nut is turning. To start a partially tightened nut will require a much higher torque than that required to keep it turning. Do not exceed the torque specified. The ratio of pounds torque to pounds pull on the stud is not an even ratio, and excess torque easily may overstress the stud.

87. Crankcase, Crankshaft, and Main Bearings (fig. 52)

a. Install Crankcase on Assembly Stand. Install crankcase on engine assembly stand (41–K–106–505) (fig. 8). Turn stand so that open end of crankcase is up.

b. Install Crankshaft Assembly. Test all main bearing studs with a torque of 700 inch-pounds to be sure they are seated. Install main bearing halves (J) (fig. 52) in their original positions in crankcase and coat them with engine oil. The thrust bearing (H) is No. 4. Lift crankshaft assembly with crankshaft lifting sling (7082025) (fig. 29) and lower it gently into crankcase, guiding connecting rods through cylinder mounting holes. Flywheel end connecting rods connect to pistons in the left bank of cylinders.

Note. In lowering crankshaft, be very careful to avoid damage to main bearing journals, main bearing studs, and cylinder mounting holes.

Install connecting rod protectors (41–P–2839–535).

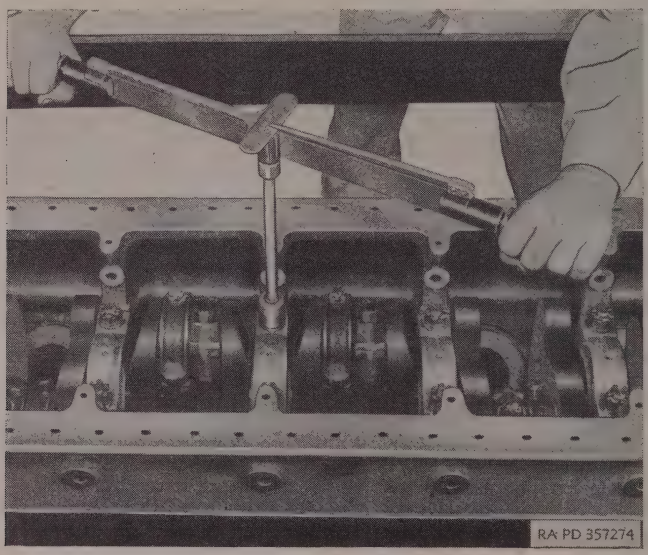


Figure 73. Torque tightening main bearing cap nuts.

c. Install Main Bearing Caps. Coat main bearing cap liners with engine oil and install them with their bearing caps in their original positions. Install main bearing cap washers with flat side against the cap. Run main bearing cap nuts on evenly and pull them initially to 650 inch-pound torque tightness (fig. 73). Next, increase torque on all nuts to 800 inch-pound. Final torque to be applied is 1,200–1,300 inch-pound. Do this by torque-tightening all nuts to 1,200 inch-pound (par. 86) and then increasing sufficiently to line up the nut with a locking wire hole in stud. Secure assemblies with locking wire.

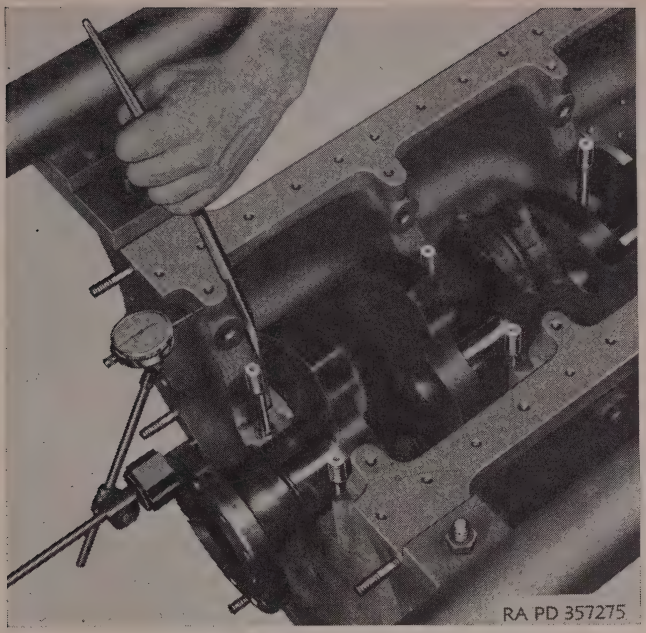


Figure 74. Checking crankshaft end play.

d. Check Crankshaft End Play (fig. 74). Install a dial indicator to the crankshaft flange. Insert pinch bar between crankshaft counterweight and crankcase housing and pry crankshaft through its limits of end play. If end play exceeds 0.017 inch, install new thrust main bearing.

e. Install Vibration Damper Counterweights. Install crankshaft damper counterweight pins and counterweights. These are secured with a counterweight stop plate held to damper hub by means of four drilled head bolts and locking wires (figs. 27 and 54).

f. Install Crankcase Cross Bolts. Install crankcase cross bolt spacers (Y) (fig. 52) and slide cross bolts (G) through them. Install washers, special nuts, and cotter pins on one end of bolts. Install washers and nuts on other ends and run nuts down evenly. Nuts should be tightened to 800–850 inch-pounds torque. Tighten them first to 800 inch-pound torque (par. 86) (fig. 75), then apply additional torque to line up cotter pin holes, and insert cotter pins.

g. Install Crankshaft Oil Seal and Oil Seal Housing (fig. 52). Use new seal. Place seal spring around crankshaft and fasten its ends together. Install crankshaft oil seal (LL) with its flat face away from crankcase. Push spring in seal across seal split line. Rotate seal, feeding spring into it as it turns. If seal is so limber that it deforms, permitting spring to slip out, support it with lower oil seal housing (FF) during spring feeding operation. Install lower and upper oil seal housings. Secure lower housing to upper housing with

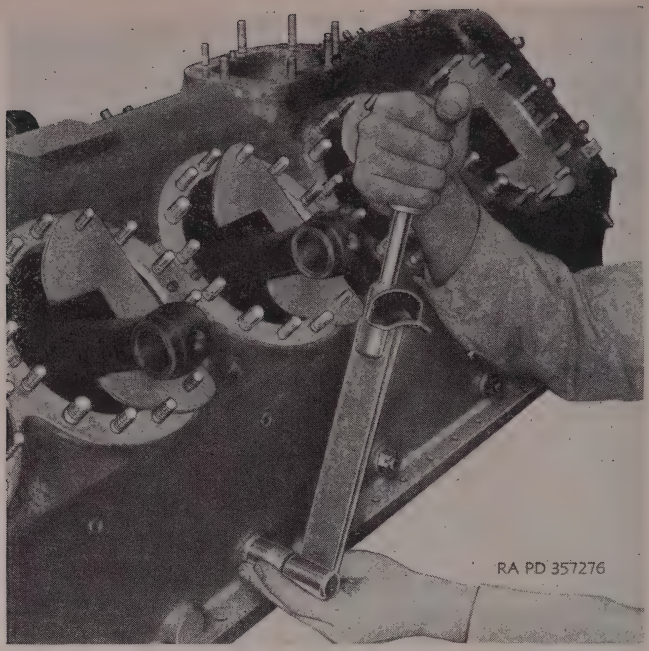


Figure 75. Torque tightening crankcase cross bolts

plain washers, slotted nuts, and locking wire. Secure housing assembly to crankcase, the lower housing with two flathead machine screws, plain washers, slotted nuts, and locking wires, and the upper housing with plain washers, drilled head bolts, and locking wire. Fasten split crankshaft oil seal retaining plate to housing with drilled head bolts and locking wire.

h. Install Engine Shroud Plate Spring Clips. If the accessory end and flywheel end spring clips are removed, install them with lock washers and drilled fillister head screws.

88. Fan Drives (fig. 44)

a. Install Fan Drive Bevel Gear Supports. Turn engine upright. Install supports (G) on machined pads of the crankcase, using new gaskets between supports and crankcase. Secure supports with plain washers, plain nuts, and lock nuts on three studs at the accessory end of each support.

b. Install Fan Drive Bevel Gears and Horizontal Shaft Assembly. Insert flywheel end horizontal shaft assembly (FF) in opening at the accessory end of crankcase. Slide it forward through bevel gear supports until it is clear of the accessory end support.

Note. Perform this operation carefully to avoid nicking or damaging the gear support bearings.

Insert accessory end bevel gear (EE) in its support. Slide horizontal

shaft back and into mesh with that gear. Insert flywheel end bevel gear in its support, meshing it with horizontal shaft.

c. Install Fan Drive Housing Assemblies. Install fan drive housing assemblies (A) with governor on the accessory end of crankcase. Governor and governor replacement cover on housing assemblies should face accessory end of engine. Secure fan housing assemblies with plain washers, plain nuts, and lock nuts.

Figure 76. Installing piston and rings.

89. Pistons, Cylinders, and Air Deflectors

a. Install Pistons in Cylinders (fig. 76). Insert piston assembly in large end of piston ring gage and compressor (41–G–534–50) and guide it into its cylinder until all rings have entered the cylinder bore. Be sure that the piston is assembled in the correct cylinder and that it is positioned according to marking on the bottom of the skirt. Cylinders are marked on the intake side of the mounting flange. Slip off the gage and compressor. Assemble all pistons to their cylinders in this manner. Install new cylinder base "O" ring gaskets.

b. Install Cylinders on Crankcase. Turn crankshaft to bring connecting rod of piston cylinder assembly to be installed, near top center. With piston pin holes exposed, place piston cylinder assembly over connecting rod, aline the piston pin bores and insert piston

pin. Center pin in piston. Remove connecting rod protector. Slide cylinder assembly over its studs. Install plain washers and run hold-down nuts down evenly. Using wrenches (41–W–872–715) and (41–W–872–710), tighten the nuts to 325–350 inch-pounds torque (fig. 24 and par. 86). Install lock nuts to secure hold-down nuts. Turn crankshaft to bring the next connecting rod near top center, and install that piston cylinder assembly. Repeat until all assemblies are installed.

c. Install Cylinder Air Deflectors (fig. 16). Lay the 10 intercylinder air deflectors in position and secure them with hooks, clamps, lock washers, and plain nuts. Position end deflectors and fasten them to their adjoining intercylinder deflectors with spacers, bolts, slotted nuts, and cotter pins. Secure end deflectors by connecting them to adjoining clamps with deflector springs. Fasten the outside dome fin air deflectors for Nos. 1 right and 6 left cylinders to their cylinder air deflectors with round head machine screws.

d. Install Rocker Box Oil Drain Lines (fig. 15). Slip a hose onto the bottom end of each of six drain lines. Install two hose clamps per hose, tightening them enough to prevent their falling off the hose. Bolt assemblies to the cylinder heads with special hollow connector bolts. Use new gaskets between drain lines and cylinder heads and between connector bolts and lines. Secure connector bolts with locking wires. Oil drain lines must be installed after installation of intake manifolds (par. 98).

90. Accessory Case and Accessories

a. Install Accessory Case Assembly. Put a new "O" ring gasket over the crankcase oil transfer tube. Install accessory case to crankcase.

Note. Install with care to prevent damage to mounting studs.

Place engine lifting hook bracket over the three top studs. Secure accessory case and bracket with plain washers, plain nuts, and lock nuts.

b. Install Accessory Drive Shaft. Install accessory drive shaft using puller (41–P–2906–280) (fig. 21). The shaft is prevented from backing out of position by a snap ring. Insert the internal snap ring, using pliers (41–P–1992–35). Do not install power take-off cover at this time as the main accessory drive gear splines must be exposed to use turning wrench (41–W–906–125) to rotate crankshaft.

c. Install Horizontal Fan Drive Shaft (Accessory End). Install horizontal shaft with remover and replacer (41–R–2378–602) (fig. 20). An internal snap ring prevents the shaft from backing out. Insert snap ring, using pliers (41–P–1992–35). Install accessory driven shaft support cover with a new gasket. Secure cover with plain washers, plain nuts, and lock nuts.

d. Install Generator. If the mounting plate has been removed from generator, install a new gasket between plate and generator and secure them together with plain washers, plain nuts, and lock nuts. Use a new gasket between generator mounting plate and generator drive shaft adapter. Secure generator and mounting plate to accessory case with plain washers and drilled head generator mounting bolts (fig. 13). Secure bolts with locking wire.

e. Install Starter. Install new starter gasket. Secure starter assembly to its mounting face with plain washers, plain nuts, and lock nuts (fig. 12).

f. Install Fuel Pump Adapter and Fuel Pumps. Install a new fuel pump mounting adapter gasket. Install adapter and secure it with plain washers, plain nuts, and lock nuts. Put new fuel pump gaskets on adapter and install fuel pumps, securing them with plain washers, plain nuts, and lock nuts.

g. Magnetos. Do not install magnetos at this time. They are installed when engine is timed (par. 94).

h. Install Oil Filter Housing Assembly. Use a new gasket between housing and accessory case. Install oil filter housing assembly and secure with plain washers, plain nuts, and lock nuts.

i. Install Oil Pressure Control Valve and Oil Filter By-pass Valve Assemblies. Use new annular gaskets between valve assemblies and accessory case. Install both valve assemblies, using wrench (41–W–3727–33) (fig. 34). Secure both valve housings with locking wire. See that both valve housing caps are secured to the housings with locking wires.

91. Transmission Case Adapter

Use a new crankcase to transmission adapter gasket. Install adapter, running the slotted nuts down evenly. Tighten nuts (par. 86) to 400–450 inch-pounds torque and secure them with locking wire. If engine lifting eye has been removed from the top of adapter, reinstall it. If engine timing pointer has been removed, install and secure it with two fillister head machine screws and locking wire.

92. Flywheel Assembly (fig. 26)

a. Install Flywheel. Install flywheel over crankshaft dowel pins and run the securing bolts down evenly with a lock under each pair of bolts. Tighten bolts (par. 86) to 950–1,050 inch-pounds torque and secure them by bending up corners of the locks (N).

Note. Always use new locks.

b. Assemble Torsion Damper. Assemble damper drive (Q) to their seats and install the assemblies in their recesses in the flywheel. Install torsion damper spacer plate (L) and one friction disc (H).

Assemble input shaft accessory drive gear (D) to torsion damper spring driven plate and damper hub plate (K), securing the three parts with drilled hex-head bolts and locking wire. Install this assembly over the drive spring assemblies. Install the other friction disc (H), pressure plate (G), torsion damper spring (F), and flywheel cover plate (C). Secure the cover plate with self-locking hex-head bolts (S). Slip the transmission input shaft oil pump drive gear (B) into position and secure it with an external snap ring, using pliers (41–P–1992–49).

93. Camshaft Drives and Valve Rockers

a. Install Intercylinder Connectors. Install new "O" ring gaskets on 10 intercylinder connectors. Slide intercylinder connectors (D) (fig. 41) over the camshafts.

b. Assemble Valve Rockers to Supports (fig. 45). Slide valve rockers (Q) on their support shafts (P) and assemble shafts to their supporting camshaft bearing cap (N) and support bracket (R).

Note. Be sure that all parts previously used are reassembled in their original positions.

c. Install Camshaft Drives (fig. 18). Secure camshaft gear housings to No. 1 cylinders with tab washers and bolts. Slide the hoses on the camshaft drive housing over camshaft drive inner supports and clamp securely.

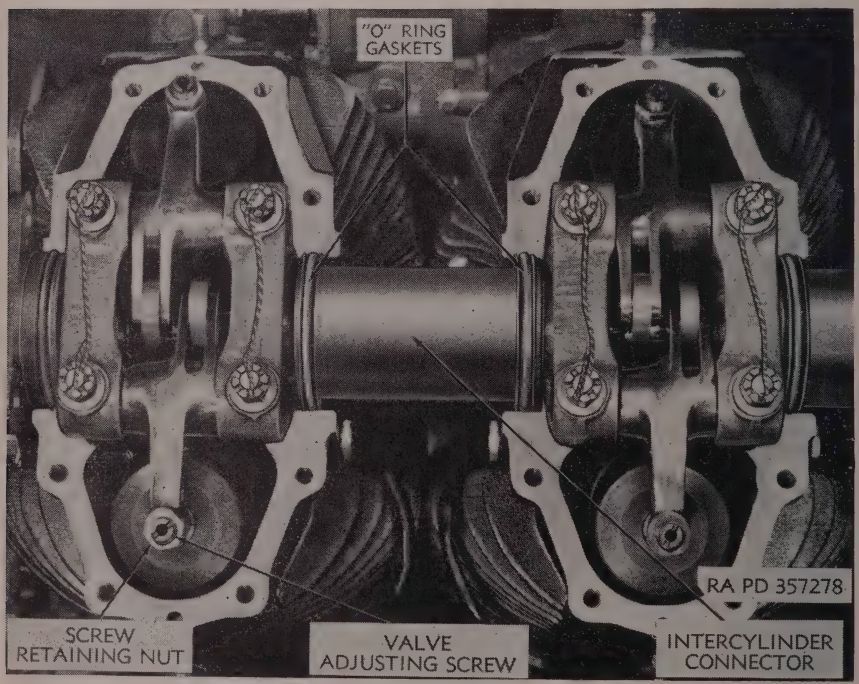


Figure 77. Valve mechanism.

d. Install Valve Rockers and Rocker Supports (fig. 77). Install rockers and supports in their original positions. Place washers over the cap and bracket studs, and run slotted nuts down evenly. Torque-

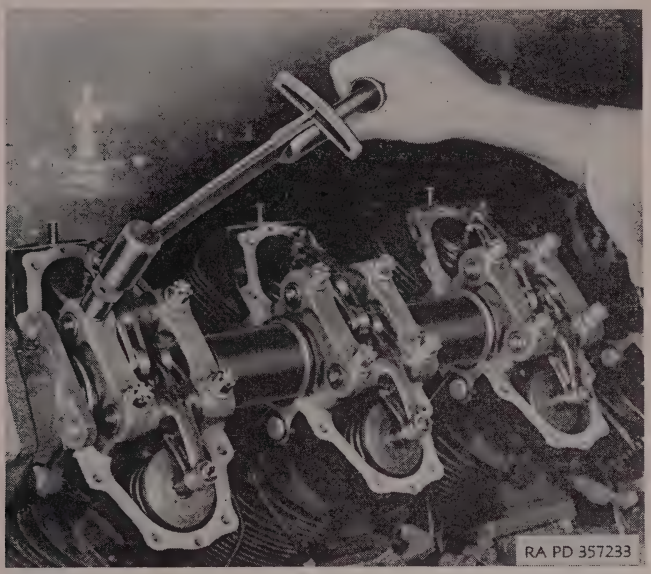


Figure 78. Torque-tightening valve rocker support nuts.

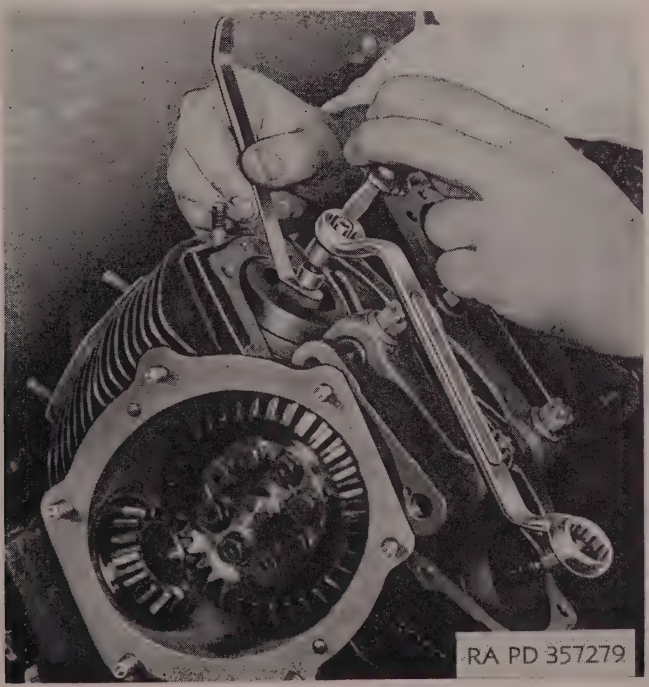


Figure 79. Adjusting valve rocker clearance with gage (41–G–415–175).

tighten nuts (par. 86) to 175–200 inch-pounds (fig. 78). Secure with locking wire.

e. Set Valve Clearances (fig. 79). Set intake valve clearances to 0.007 inch and exhaust valve clearances to 0.020 inch. Clearance setting must be done with rocker rollers on the base circles of cams, opposite high points of cams. Loosen lock nut. Insert feeler gage (41–G–415–175) between valve stem tip and adjusting screw pad and turn screw until proper clearance is obtained. Hold adjusting screw in that position while tightening lock nut.

94. Valve and Magneto Timing

a. Set Right Bank Valve Timing.

(1) Set No. 1R and No. 1L cylinder intake valve clearances to 0.100 inch, using method described in paragraph 93*e*. Timing marks are on flywheel, and timing pointer is on the transmission adapter. Rotate crankshaft clockwise, as viewed from accessory end, with engine turning wrench (41–W–906–125) until timing mark "V–ENG, 1R–IN, CL .100 CLR" is alined with the timing pointer. Turn right camshaft counterclockwise, as viewed from accessory end, until No. 1R intake valve has just closed. The closing point is determined precisely by attempting to rotate intake valve rocker roller by hand as camshaft is being turned. Valve is closed at instant roller becomes free (rocker roller will turn with a small amount of drag). Hold camshaft at this point and insert right camshaft drive quill (fig. 17), using remover and replacer (41–R–2378–575). When installing this quill, feel around for a position in which it will enter its mating splines easily. Do not drive it in.

(2) Check the timing as follows:

(*a*) Rotate camshaft one-eighth turn counterclockwise, as viewed from accessory end.

(*b*) Slowly rotate crankshaft clockwise, attempting to rotate No. 1R intake rocker roller as crankshaft turns. Stop turning at the instant roller becomes free (rocker roller will turn with a small amount of drag).

(*c*) Observe positions of timing mark and timing pointer. If they are alined, engine is timed correctly. If they are misalined by more than one-fourth inch, withdraw the camshaft drive quill and repeat timing procedure.

Note. If correct timing cannot be accomplished as outlined above, it may be necessary to install camshaft drive quill when the timing mark is one-eighth to one-fourth inch out of line with the timing pointer.

(3) Install camshaft outer oil transfer plug, using puller (41–R–

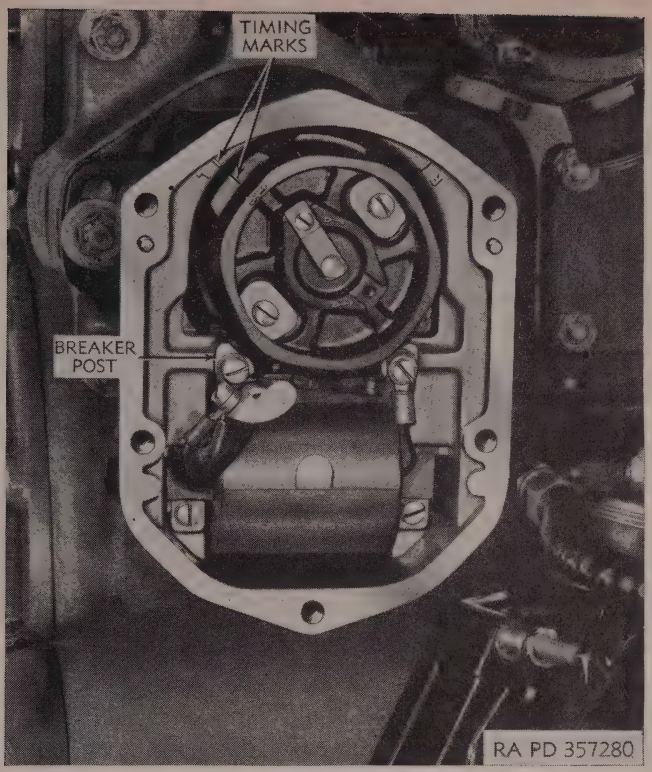


Figure 80. Magneto timing marks.

2378–575). Secure plug with an internal snap ring, using pliers (41–P–1992–35).

b. Set Right Bank Magneto Timing.

(1) After timing right bank valves, rotate crankshaft in normal direction until timing mark "V–ENG, 1R, IGN" is alined with pointer.

Note. If magneto timing is performed independently of valve timing, line up the flywheel timing mark and pointer with No. 1R cylinder on its compression stroke.

Install new magneto gaskets. Remove magneto covers and aline timing marks on the two right bank magnetos (fig. 80). Install them with mounting studs centered in the adjusting slots.

Caution: Use the timing line that is marked "L" on the magneto housing. The timing line marked "R" is for rotation in the opposite direction.

Fasten magnetos with plain washers, plain nuts, and lock nuts.

(2) Synchronize the magnetos, using a timing light (41–L–1439), as follows:

(*a*) Secure timing light ground cable clip to one magneto housing.

(*b*) Clip one of two remaining leads to breaker post (fig. 80) on top magneto, and other lead to breaker post of bottom magneto.

(*c*) Rotate crankshaft one-eighth turn in reverse direction. Then bring it slowly forward until timing lights go out.

(*d*) Both lights should go out at the same time the flywheel timing mark alines with the pointer. If they do not, loosen magneto fastening nuts and adjust magnetos until this condition is achieved. Tighten fastening nuts.

(*e*) When magnetos are synchronized and timed, observe whether magneto timing marks are alined. If they are not alined, it means that the breaker point adjustment is incorrect. Adjust breaker points (TM 9–1825E), and reinstall and time magnetos.

(*f*) Install magneto covers and secure with plain washers, lock washers, and bolts.

c. Set Left Bank Valve Timing. After timing right bank magnetos, rotate crankshaft in normal direction until flywheel timing mark "V–ENG, 1L–IN, CL., .100 CLR" alines with timing pointer. Set and check left bank valve timing in the same manner as right bank (*a* above).

d. Set Left Bank Magneto Timing. After timing left bank valves, rotate crankshaft in the normal direction until flywheel timing mark "V–ENG, 1L, IGN" is alined with pointer. Install, time, synchronize, and check left bank magnetos in the same manner as those of right bank (*b* above).

e. Install Power Take-Off Cover. Install power take-off cover with new gasket. Secure it with bolts, nuts, washers, and lock washers.

95. Rocker Box Covers

Install all rocker box covers. Insert the eight ignition cable clip spacers in outside holes, accessory side, of rocker covers for cylinders Nos. 1, 3, and 6 on each bank, and outside holes, flywheel side, on No. 4 cylinders. Use plain washers and lock washers under spacers and finger-tighten. Install rocker box cover bolts with plain washers and lock washers and finger-tighten. Fasten rocker box cover with new gaskets to No. 6R and 6L cylinders and secure with bolts and tab washers. Fasten 1R and 1L rocker box covers to their camshaft gear housing with bolts and tab washers. Tighten rocker box cover bolts and ignition cable clip spacers.

96. Oil Pump and Oil Lines

a. Install Oil Pump. Turn engine so that oil pump can be installed from the side. Install oil pump assembly on the bottom of accessory case (fig. 30), making certain that oil pump drive and driven bevel gears are meshed properly. Secure pump with plain washers, slotted nuts, and locking wires.

b. Installing Oil Pump Inlet Tubes (fig. 52). Turn the engine so that the open side of crankcase is up. If it was removed, install scavenge oil line support bracket (CC) on special studs in crankshaft oil seal lower housing. Secure bracket with slotted nuts and locking wire. Install oil pressure pump inlet line bracket (L) on crankcase bosses at No. 1 main bearing. Secure bracket with drilled head bolts and locking wire. Slip scavenge pump inlet line (N) into its oil pump housing port and fasten it to its bracket with drilled bolts, slotted nuts, and locking wire. Secure the line to crankcase bosses at Nos. 2, 4, and 6 main bearings, with clips, drilled head bolts, and locking wire. Insert oil pressure pump inlet tube (M) into its oil pump inlet port and secure it to the support bracket with a drilled bolt, slotted nut, and cotter pin.

97. Oil Pan (fig. 52)

a. Install Oil Pan and Oil Sump Screens. Install oil pan and secure it with four nuts, two on each side of the pan. Assemble oil sump screens (S) to their housings, using new annular gaskets between the sump screen plugs (Q) and housings (V), and new "C" ring gaskets in housing grooves. Install sump screen and housing assemblies to oil pan, using new gaskets.

Note. Do not force assemblies over the oil pump inlet lines, as severe damage to the screens may result. Correct the misalinement if interference between the tubes and screens occurs.

Secure the housings with plain washers and drilled head bolts. Secure the bolts and the oil sump screen plug with locking wires. Turn engine upright and secure oil pan, using plain washers, plain nuts, and lock nuts on studs. Use plain washers, lock washers, and hex-head bolts in tapped holes. Install a pipe plug in the tapped hole on right side of the oil pan.

b. Install Oil Filler and Indicator Assembly. Install a new gasket on the mounting pad. Install oil filler bracket on No. 6 cylinder. Place filler assembly on oil pan and secure it with plain nuts and lock nuts. Place filler clamp around tube and secure it to bracket with bolts and lock washers. Install oil level indicator in filler and place cap on the filler.

98. Intake Manifolds and Carburetors

Turn engine upright. Install new intake manifold gaskets. Install intake manifold subassemblies (fig. 66) and secure them with plain washers, plain nuts, and lock nuts. Center the hoses over the manifold joints and tighten hose clamps. Install new intake hot-spot manifold gaskets. Secure intake hot-spot manifolds to the right center manifold sections with plain washers, plain nuts, and lock nuts. Install pipe lugs in holes in the right center manifold sections and in intake hot-spot sections, except the holes for air metering valves in the bottom of the left intake manifold hot-spot section. Install new carburetor gaskets and secure carburetors to hot-spot manifolds with plain washers, plain nuts, and lock nuts. Oil drain lines now can be installed (par. 89*d*).

99. Primer Lines (fig. 12)

If primer nozzle assemblies have been removed from cylinders, install them. Connect intercylinder primer line union tees to the nozzle assemblies. Install intercylinder primer lines. Cap flywheel end outlets of the tees in No. 6 cylinders with primer tee hole plug assemblies. Install nipples in the top of the primer block which is integral with the accessory case. Connect long tube assemblies between primer block and the No. 1 cylinders.

100. Throttle Linkage (figs. 3 and 59)

Install new camshaft gear housing cover gaskets. Install throttle linkage assembly. Secure camshaft gear housing covers with plain washers, plain nuts, and lock nuts. Fasten cross shaft center bearing housing to engine lifting hook bracket with plain washers, drilled head bolts, and locking wire. Connect rod assemblies to carburetors with bolts and self-locking nuts.

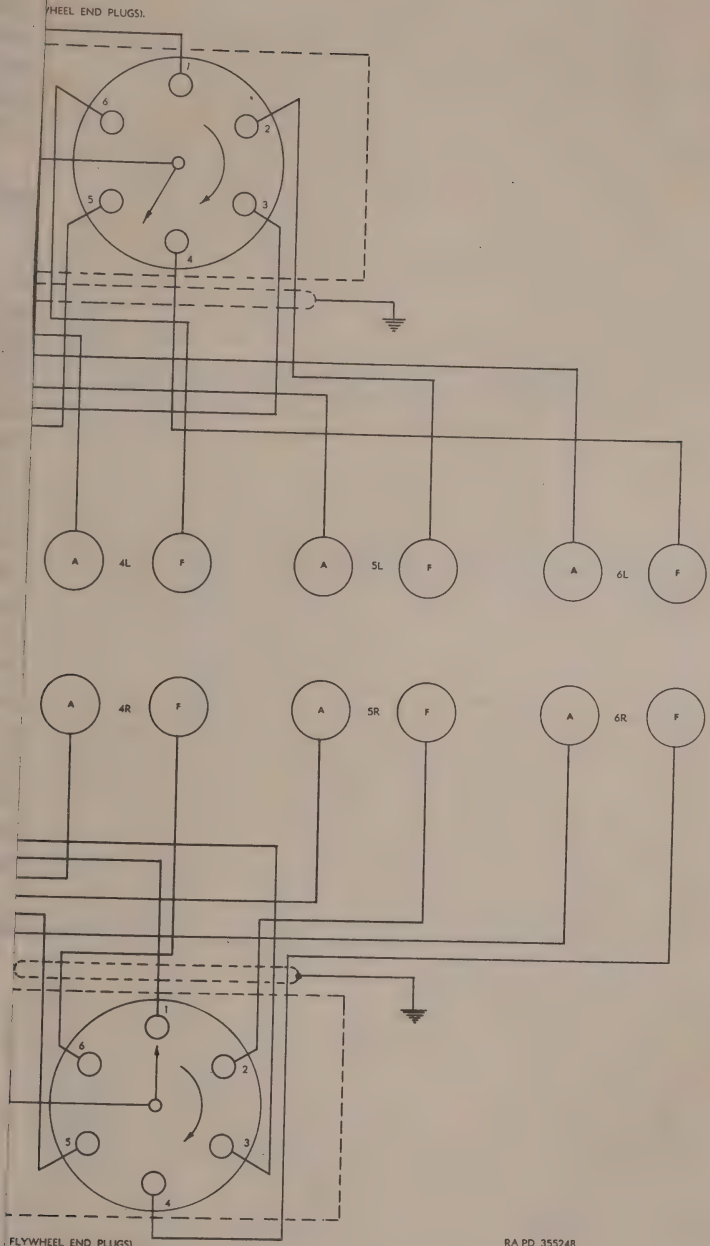
101. Spark Plugs, Booster Coils, and Ignition Harnesses (fig. 81)

a. Install Spark Plugs. Insert spark plugs in their holes with the inserting wrench (41–W–3306–500).

Note. Be sure a serviceable gasket is under each spark plug.

Run plugs down and tighten to 200–225 inch-pounds torque (par. 86).

b. Install Ignition Harness Assemblies. Install ignition harness assemblies. Secure rubber-lined harness clips to clip spacers with lock washers and bolts. Fasten magneto conduit adapters to magneto covers with screws and lock washers. Use new gaskets be-


WHEEL END PLUGS).
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FLYWHEEL END PLUGS)
RA PD 355248

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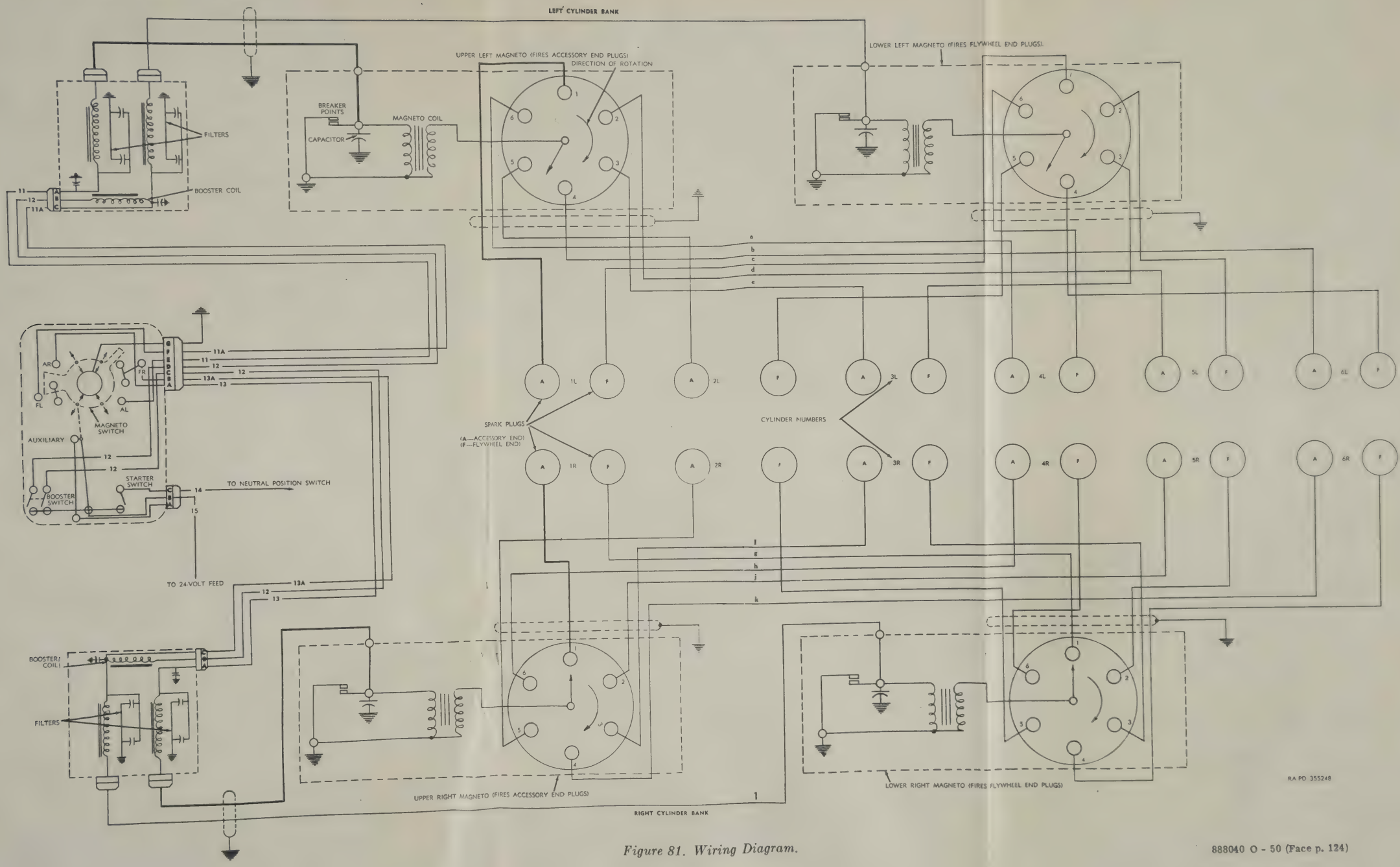

Figure 81. Wiring Diagram.

tween adapters and magneto covers. Install harness cables to spark plugs with a crowfoot wrench (41–W–871–70).

c. Install Booster Coils and Cable Assemblies Install booster coil brackets on their mounting pads on top of starter and generator mounting bosses. Secure with lock washers and plain nuts. Mount booster coils to the brackets with cable connection up. Secure with lock washers and machine screws. Install cable assemblies between the booster coils and magnetos.

102. Engine Shroud (fig. 14)

If the intercylinder shroud cover assemblies have been removed, assemble them to top engine shroud plate assembly (L). Install a special fabric washer on the stud atop each cylinder. Install top shroud plate assembly (B) and then another set of fabric washers. Secure with plain washers, slotted nuts, and cotter pins. Set flywheel end shroud plate (F) in four clips mounted on crankcase. Secure it to the top plate. Connect the throttle lever to governor rod assemblies to the governor through holes provided in the assessory end shroud cover plate (N). Secure the rods to the governor with bolts and self-locking nuts. Many governors have an external oil line, from an oil passage outlet on the right side of accessory case to the governor adapter. Such installations may be distinguished by the presence of a tapped hole in the adapter. Install this oil line before completing assembly of engine shrouds. Insert right- and left-hand accessory end shroud plates (M and P) in their crankcase clips and bolt to the top plate. Secure the cover plate (N) to accessory end shroud plates (M and P). Fasten the primer tube for the right bank of cylinders to the right- and left-hand accessory end shroud plates with loop-type clamps and machine screws, secured to clip assemblies mounted in the shroud plates.

103. Exhaust Manifolds

Place new exhaust flange gaskets over exhaust port studs. Install exhaust manifold subassemblies (fig. 67) and secure them with plain washers and self-locking nuts.

104. Cooling Fans

a. Install Fan Housing and Fan Assemblies. Place fan rotor housings on the fan drive housings and secure them with $\frac{5}{16}$–$\frac{3}{4}$ x $\frac{3}{32}$ washers, slotted nuts, and cotter pins. On most engines, the rotor housings are fastened to the top engine shroud plate with three bolts (fig. 14). These bolts must be installed before the fan assemblies are installed. Install fan assemblies (thin edges of blades must be up), and secure to the vertical drive shafts with special slotted nuts

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and cotter pins. Install fan drive vertical shaft covers (R) (fig. 43) and secure with special round head machine screws.

b. Install Top Fan Shroud Plate. Install plates (B and D) (fig. 14) and secure to top engine shroud plate.

c. Install Cooling Fan Vanes. Install fan vanes (A) (fig. 14) and secure to top fan shroud plates. Install exhaust manifold hole cover plates (C) and secure them.

105. Breather and Vent Lines

a. Install Breather Lines.

(1) *Oil filler to carburetor breather line.* Install oil filler to carburetor breather line. Connect it to the elbow in the carburetor and to the oil filler with hoses and thumb-screw hose clamps.

(2) *Crankcase to oil filler breather line.* The crankcase to oil filler breather line is connected to the oil filler line and crankcase elbow fitting with hoses and thumb-screw hose clamps. The line is supported by a clamp fastened to a loop-type support clamp which encircles the intake manifold. The clamps are fastened together with bolts, lock washers, and plain nuts.

(3) *Air metering valves.* Install air metering valve assemblies in bottom of left intake hot-spot manifold. Install air metering valve elbow and T fittings, elbow in the outermost valve, and T in the inner valve. Connect elbow and T with a hose secured with thumb-screw clamps.

(4) *Accessory case to air metering valve breather line.* If removed, install an adapter elbow in accessory case left side breather outlet. The right outlet should be plugged. Connect the line to the adapter elbow and the air metering valve tee fitting with hoses secured with thumb-screw clamps. The line is supported by clamps which are fastened to loop-type support clamps which encircle the intake manifold just in front of Nos. 1 and 2 left intake ports. The clamps are fastened together with bolts, lock washers, and plain nuts.

b. Install Vent Lines.

(1) *Magneto vent lines.* Magneto vent line fittings are installed in magneto housings near the bottom of the flywheel side of each housing. Fit upper magnetos with a 45° elbow and lower magnetos with a tee. Connect upper and lower magneto fittings with a vent hose. Connect remaining T outlet on each side to intake manifold fitting with a hose. Support magneto to manifold hoses with clips fastened to booster coil bracket with machine screws. A 90° elbow at flywheel end of each harness and a 45° elbow in each carbure-

tor are connected with a hose. Support these hoses with loop-type supports around hoses and ignition harnesses. Fasten supports together with bolts, lock washers, and nuts.

(2) *Starter vent line.* Connect between the 90° elbow and reducer bushing assembly in the left carburetor and the 45° elbow in starter with a vent hose. Two loop-type support clamps, one around ignition harness and the other around the hose, are fastened together with a bolt, lock washer, and nut.

Note. Be sure vent lines are installed so that no rubbing or chafing occurs.

106. Fuel Lines and Fittings

a. Fittings.

(1) Fit left carburetor with an elbow into which a nipple is threaded. Fit right carburetor with a similar nipple.

(2) Fuel pump inlets are plugged. Fit outside pump outlet with a tee and inside pump outlet with an elbow. Use special straight fitting to connect this elbow to a tee. Connect this tee and the tee in the outer pump with the fuel pump connector tube assembly.

b. Hoses. Connect left bank fuel hose to outer fuel pump tee outlet and to carburetor nipple. Support hose with clips secured to Nos. 1L and 2L rocker box covers. Connect right bank fuel hose to inner fuel pump tee and to right carburetor nipple. Clip hose to front and to right side of accessory case. Support it further with two loop-type supports around the hose and fasten to two around the intake manifold. Fasten these supports with bolts, lock washers, and plain nuts.

Section XVI. TESTS AND ADJUSTMENTS

107. Oil Pressure

Oil pressure can be raised (par. 74*e*(2)), but not lowered with the type of control valve used. If oil pressure at operating temperature is too high at 2,000 rpm, install a new control valve. If pressure is too low, adjust it to 60–70 psi.

108. Throttle Linkage (figs. 3 and 59)

a. To adjust the throttle linkage, proceed as in *b* through *j* below.

b. Shorten both carburetor to cross shaft rods as far as possible and disconnect them from carburetors. Open both carburetors to their full throttle stops.

c. Disconnect the rods at the governor.

d. Connect the carburetor rods to the carburetors, adjusting them so that both carburetors are at full throttle together.

e. Keep the carburetors at full throttle and adjust the cross shaft to governor lever rod so that the lever will be 0.010 inch off the governor stop when reconnected to the rod.

f. Reconnect the lower rod to the governor.

g. Connect the throttle-actuating mechanism to the cross tube right end lever.

h. Adjust the cross tube lever to governor lever rod to the length required to make the connection.

i. After the engine has been run-in to 2,000 rpm, check the manifold pressures with a vacuum gage. They should be balanced to within 1 inch (of mercury), by adjusting the carburetor rods, when operating at approximately 20 inches of manifold pressure.

j. Vacuum-test and adjust idle as outlined in the pertinent operator's manual.

109. Accessories

Tests and adjustments to accessories are outlined in the pertinent operator's manual and pertinent technical manuals.

Section XVII. RUN-IN TEST

110. Preparation for Run-in

Install the engine to a dynamometer or transmission. Pre-oil the engine by forcing oil under pressure into the oil system. This insures adequate lubrication to the engine parts until the engine pump supply reaches them. If no pre-oiling equipment is available, fill all external oil lines and the oil coolers with the proper grade oil. See that an adequate supply of oil is in the oil plan. Adjust throttle linkage as outlined in paragraph 108*b* through *h*. Complete steps in paragraph 108*i* and *j* when the run-in has progressed to 2,000 rpm.

111. Engine Run-in

a. Run-In Schedules. A rebuilt engine should be started and run-in in accordance with one of the following schedules. If any piston rings or cylinders on the engine have been changed, or the cylinders honed, use the long run-in. If the piston rings and cylinder bores are unchanged, use the short run-in.

(1) *Long run-in.*

Period	*Minutes*	*RPM*	*BHP (approx.)*
1	30	1, 000	0
2	30	1, 000	91
3	30	1, 200	131
4	30	1, 400	179
5	30	1, 600	234
6	30	1, 800	296
7	30	2, 000	365
8	30	2, 200	442
9	30	2, 400	525
10	30	2, 600	616
11	15	2, 800	max
12	15	2, 400	max
13	15	2, 000	max
14	15	1, 600	max

(2) *Short run-in.*

Period	*Minutes*	*RPM*	*BHP (approx.)*
1	15	1, 000	0
2	15	1, 200	131
3	15	1, 600	234
4	15	2, 000	365
5	15	2, 200	442
6	15	2, 400	525
7	15	2, 600	616
8	15	2, 800	max

b. Oil-Consumption Check. Oil consumption may be measured in the following manner:

(1) Repair all oil leaks.
(2) Run the engine and shut it down when the oil is at operating temperatures.
(3) Allow 10 minutes for foam on the oil to settle and measure the oil level.
(4) Run for 1½ hours at 2,800 rpm and maximum horsepower.
(5) Shut down and allow 10 minutes for foam on the oil to settle.
(6) Measure the amount of oil required to raise the oil to its original level.
(7) Maximum allowable oil consumption is 2 gallons in 1½ hours. If it exceeds that, investigate the cause.

112. Governor Adjustment

Upon completing run-in, adjust governor as outlined in pertinent operator's manual.

CHAPTER 5

HYDRAULIC GOVERNOR

Section I. DESCRIPTION

113. Hydraulic Governor

The hydraulic governor is mounted on the front fan drive housing and is gear-driven from the fan drive. Its function is to maintain engine speed below predetermined limits regardless of engine load. The governor is essentially a fly-ball type. The rotating mechanism consists of balls riding between a flat disc and a conical cover. Axial movement of the cover, occasioned by the centrifugal force of the rotating balls, actuates a pilot valve controlling a "servo" cylinder. This servo mechanism controls the governor to carburetor linkage.

Section II. REBUILD OF HYDRAULIC GOVERNOR

114. Disassembly of Hydraulic Governor (fig. 82)

a. Withdraw the centrifugal assembly (A, B, C, D, E). Remove ring (E) with pliers (41–P–1992–27) and separate the parts. Remove stop screw (CC) from housing and withdraw hydraulic valve (F), spring, and washer. The drive shaft assembly (A) is not disassembled.

b. Remove four cap screws and lock washers from the cylinder head flange, pull out the head assembly (M), and remove the piston spring. Strip off head gasket.

c. Drive out the pin holding the cylinder yoke to the piston rod and pull the yoke from the rod.

d. Remove the dust boot.

e. Remove the dust cap (R) from the housing, unscrew the nut holding the adjusting screw (T), remove the nuts and screw, and lift off the sealing washer (U). Remove the two fillister-head machine screws, which hold the cover (W) to the housing, and strip off the gasket.

f. Remove the plug (Y) from the housing which covers the port of the metering screw (Z), turn out the metering screw, and lift out the spring.

115. Cleaning, Inspection, and Repair of Hydraulic Governor

a. Cleaning.

(1) Clean the dust boot with carbon tetrachloride.

(2) Wash all other parts in dry-cleaning solvent or volatile mineral spirits paint thinner.

b. Inspection.

(1) Check the castings for cracks and see that the mating surfaces are smooth.
(2) Check the piston rod for scoring.
(3) Check the cylinder walls for scores or abrasions.
(4) Check the movement of piston in cylinder and the hydraulic valve in its bore.
(5) Check the springs for signs of failure.

c. Repair.

(1) Replace all worn parts.
(2) If piston rod is scored, pull piston and rod from head and replace chevron packing in cylinder head. Smooth piston rod with crocus cloth.
(3) Clean up all scratches or abrasions on cylinder walls and piston with crocus cloth.
(4) Remove all burs from the oil passage openings. The edges of these openings should be smooth. Clean them carefully with a scraper, if necessary.

116. Assembly of Hydraulic Governor (fig. 82)

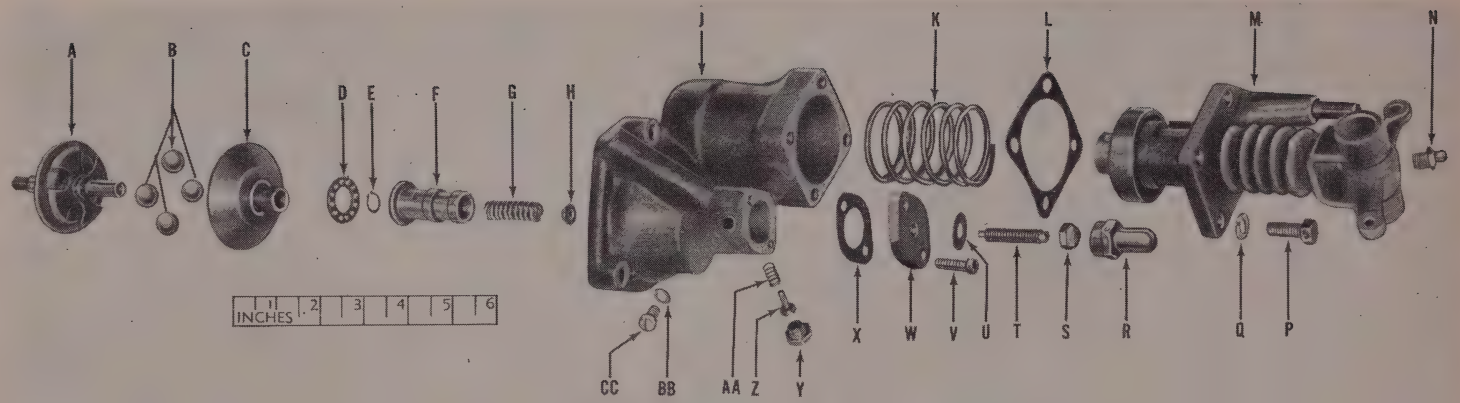
a. Assemble the upper race over the centrifugal drive shaft assembly (A) with the four balls in their recesses, and replace the ring (E). Install the thrust bearing (D) and hydraulic valve (F) on upper race. Insert spring into valve and place spring washer (H) on end of spring. Insert the complete assembly into housing and install the stop screw (CC) and its washer.

b. Thread adjusting screw (T) into cover (W). Place sealing washer (U) over screw, install elastic nut (S), but do not tighten. Place a new gasket on housing and install cover assembly. Be sure the dog point of the adjusting screw seats in the washer (H). Secure cover with drill-head fillister screws and locking wire. Install dust cover (R).

c. Insert the metering screw spring (AA), metering screw (Z), and its plug (Y).

d. If the piston and rod were removed, reassemble them in the cylinder head. Place the piston compression spring (K) in the cylinder and install the assembly with a new gasket in the same relative position as in figure 82. Secure with lock washers and drilled-head cap screws. Install locking wires.

e. Install dust boot. Place cylinder yoke on piston rod and secure with drive pin. See that ends of boot are seated in grooves in head and yoke.



A—SHAFT, DRIVE, ASSY—NI-52517A
B—BALL—NI-50042-10
C—RACE, UPPER—NI-52652
D—BEARING, THRUST—NI-50021-2
E—RING, RETAINING—NI-52409-6
F—VALVE, HYDRAULIC—NI-52500
G—SPRING, COMPRESSION—NI-51045-29
H—WASHER, SPRING—NI-52503
J—BODY—NI-52511A
K—SPRING, COMPRESSION—NI-51045-28
L—GASKET, CYLINDER—NI-51276
M—HEAD, CYLINDER, ASSY—NI-52512A
N—FITTING, GREASE—NI-51847
P—SCREW, CAP—NI-50134-10
Q—WASHER, LOCK—NI-50034-6
R—CAP, DUST—NI-51279
S—NUT, ELASTIC—NI-51046-8
T—SCREW, ADJUSTING—NI-51281
U—WASHER, SEALING—NI-51284
V—SCREW—NI-51404-6
W—COVER—NI-52501
X—GASKET—NI-52502
Y—PLUG—NI-52508
Z—SCREW, METERING—NI-52507
AA—SPRING—NI-51045-22
BB—WASHER, STOP SCREW—NI-52653
CC—SCREW, STOP—NI-52651

Figure 82. Governor assembly—exploded view.

CHAPTER 6

SERVICEABILITY STANDARDS

117. Accessory Case (par. 46)

a. Interferences.

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
1	Accessory driven shaft support and support bearing	0. 002		0. 004	
2	Accessory drive gear bearing (accessory end) and accessory case	0. 002		0. 005	
3	Accessory drive gear bearing (flywheel end) and accessory case	0. 002		0. 005	
4	Starter drive gear hub bearing and accessory case	0. 002		0. 005	
5	Accessory driven shaft bearing and accessory case	0. 002		0. 005	
6	Ignition drive driven bevel gear bearings and accessory case	0. 002		0. 004	
7	Oil pump drive bevel gear bearing and accessory case	0. 002		0. 005	
8	Fuel pump drive shaft adapter and adapter bearing	0. 002		0. 005	

b. CLEARANCES.

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
9	Accessory driven shaft support and accessory case	0. 000		0. 002	
10	Oil pump housing and accessory case	0. 000		0. 002	
11	Accessory driven shaft support bearing and shaft	0. 0025		0. 0045	0. 0065
12	Accessory drive shaft bearing (accessory end) and drive shaft	0. 0045		0. 0055	0. 0075
13	Accessory drive shaft bearing (flywheel end) and drive shaft	0. 005		0. 007	0. 009
14	Accessory driven shaft bearing and shaft	0. 0045		0. 0055	0. 0075
15	Oil pump drive bevel gear bearing and bevel gear	0. 004		0. 005	0. 0075
16	End clearance, main accessory drive shaft	0. 014		0. 022	

118. Camshaft (par. 49)

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
17	Diameter of all journals	1. 309		1. 310	See ref. No. 21
18	Out-of-round journals			0. 001	0. 002
19	Run-out of center journal when supported on end journals			0. 002	0. 015

119. Camshaft Bearings (par. 49)

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
20	Diameter, all bearings	1. 312		1. 313	See ref. No. 21
21	Clearance between camshaft journals and bearings	0. 002		0. 004	0. 006

120. Camshaft Gear Train Clearances (par. 49)

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
22	Camshaft drive inner support and accessory case (R and L)	0. 0003		0. 0023	0. 0035
23	Camshaft drive inner bevel gear and inner support (R and L)	0. 0025		0. 0045	0. 0065
24	Camshaft drive inner oil transfer plug and inner bevel gear (R and L)	0. 0025		0. 0005	0. 0005
25	Camshaft drive inner and outer oil transfer plugs and camshaft drive quill (R and L)	0. 0015		0. 0035	0. 005
26	Camshaft drive outer oil transfer plug and outer bevel gear (R and L)	0. 0005		0. 0020	0. 003
27	Camshaft drive outer bevel gear and support (R and L)	0. 0025		0. 0045	0. 0065
28	Camshaft drive outer support and camshaft gear housing (R and L)	0. 0000		0. 0020	
29	Camshaft journal (R and L) and camshaft gear housing	0. 0025		0. 0045	0. 0065

121. Connecting Rod, Bushing, and Bearing (par. 63)

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
30	Bore diameter of large (crankshaft) end	3. 5315		3. 5320	
31	Inside diameter of bearing when installed with proper torque on bolts	3. 2525		3. 2540	See ref. No. 34.
32	Rod bearing thickness at ends	0. 1389		0. 1392	0. 1379
33	Rod bearing thickness at center	0. 1394		0. 1397	0. 1384
34	Clearance—connecting-rod bearing and crankpin	0. 0035		0. 006	0. 008
35	Side clearance of rod on crankshaft	0. 009		0. 017	0. 020
36	Interference—outside diameter of piston pin bearing and inside diameter of rod	0. 002		0. 0035	

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
37	Inside diameter of piston pin bearing.	1. 3762		1. 3764	See ref. No. 38
38	Clearance—piston pin and bearing	0. 0010		0. 0014	0. 002
39	Allowable twist of connecting rod	0. 0005/in. of bearing length			

122. Cooling Fan and Clutch (par. 52)

a. Clearances.

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
40	Fan hub ball bearing and clutch outer housing bearing liner	0. 001		0. 0006	
41	Fan hub and clutch oilite bearing	0. 003		0. 007	

b. Interferences.

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
42	Fan hub ball bearing and fan hub	0. 0000	-------	0. 001	
43	Fan clutch ball diameter—½ in.				
44	Fan clutch springs:				
	0.69-in. free length				
	0.41-in. solid height				
	Scale reading: 4.25±0.25 lb at 0.530-in. length.				

123. Crankshaft (par. 63)

a. Main Bearing Journals.

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
45	Diameter	3. 5010	-------	3. 5020	See ref. No. 101
46	Out-of-round	-------	-------	0. 001	0. 002
47	Taper in length of one journal (taper must be uniform)	-------	-------	0. 0005	0. 001
48	Run-out, main journals Nos. 2, 3, 5, and 6 when supported at journals Nos. 1 and 7	-------	-------	0. 015	0. 025
49	Run-out, main journal No. 4 when supported at journals Nos. 1 and 7	-------	-------	0. 025	0. 035

b. Connecting Rod Journals.

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
50	Diameter	3. 2480		3. 2490	See ref. No. 34
51	Out-of-round			0. 001	0. 002
52	Taper in length of one journal (taper must be uniform)			0. 0005	0. 001
53	Crankshaft end play	0. 008	0. 010	0. 012	0. 017
54	Crankshaft to be in dynamic balance within ¼ oz-in. at 2,800 rpm.				

c. Interferences.

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
55	Dowel pins and crankshaft	0. 0000		0. 0012	0. 0000

124. Cylinders (par. 55)

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
56	Bore diameter 1 in. from bottom of skirt (bottom of ring travel)	5. 746		5. 749	5. 759 (See text.)
57	Bore diameter opposite center of barrel fins	5. 7425		5. 7455	5. 755 (See text.)
58	Bore diameter ¾ in. from top of barrel (top of ring travel)	5. 7407		5. 7437	(See text.)
59	Out-of-round			0. 001	0. 003

125. Damper, Crankshaft (par. 63)

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
60	Side clearance—counterweight and crankshaft damper hub	0. 006		0. 014	0. 020
61	Counterweight pin diameter	1. 3647		1. 3657	1. 363
62	Counterweight pin hole diameter	1. 8125		1. 8140	1. 8160
63	Damper hub pin hole diameter	1. 8125		1. 8140	1. 8160

126. Fan and Governor Drive Gear Trains (pars. 52 and 53)

a. Clearances.

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
64	Fan drive horizontal shaft end pilot and accessory driven shaft	0. 0005		0. 0025	
65	Fan drive horizontal shaft end pilot and fan drive bevel gears (both fans)	0. 001		0. 003	
66	Fan drive bevel gears and support bearings	0. 0025		0. 0045	0. 0065
67	Fan drive housing and bevel gear support (both fans)	0. 001		0. 004	
68	Fan driven bevel gears and fan tower bearing surface (both fans)	0. 0025		0. 005	0. 007
69	Fan drive vertical shaft end pilot and driven bevel gear (both fans)	0. 001		0. 003	
70	Cooling fan hub spacer and fan drive vertical shaft (both fans)	0. 0006		0. 0021	
71	Fan drive bearing to bearing liner (both fans)	0. 0001		0. 0012	0. 002
72	Governor drive bevel gear and bearing surface	0. 0025		0. 005	0. 007
73	Governor adapter and fan drive housing	0. 001		0. 005	
74	Governor adapter bearing and governor drive driven bevel gear	0. 0025		0. 0045	0. 006

b. INTERFERENCES.

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
75	Fan drive bevel gear support bearing and support	0. 0005		0. 0025	
76	Fan drive bearing liner and housing	0. 001		0. 005	
77	Fan drive vertical shaft and bearing	0. 0001		0. 0009	0. 001

127. Flywheel Torsion Damper Drive (par. 77)

a. CLEARANCES.

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
78	Flywheel pilot and crankshaft flange	0. 0005		0. 0025	
79	Crankshaft and transmission shaft ball bearing	0. 0008		0. 0006	

b. INTERFERENCES.

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
80	Crankshaft dowel pins and flywheel	0. 000		0. 0012	
81	Flywheel and torsion damper pressure plate dowel pins	0. 0004		0. 0016	
82	Flywheel torsion damper drive spring data: 1.78-in free length (approx). 1.375 max solid height. Scale reading: 36.5 lb at 1.75-in length.				

128. Fuel Pump Gear Train Clearances (par. 46)

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
83	Starter gear hub and fuel pump drive shaft adapter bushing	0. 003		0. 005	0. 007
84	Fuel pump drive adapter and accessory case	0. 001		0. 003	
85	Fuel pump drive adapter bearings and fuel pump drive driven shaft	0. 0025		0. 0045	0. 0065

129. Generator Gear Train (par. 46)

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
86	Generator drive idler gear bracket and gears	0. 0025		0. 0045	0. 0065
87	Generator drive shaft and accessory case bearing bore	0. 0025		0. 0045	0. 0065
88	Generator drive shaft adapter and accessory case	0. 000		0. 003	
89	Generator drive shaft and shaft adapter bore	0. 0025		0. 0045	0. 0065

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130. Magneto Gear Train (par. 46)

a. CLEARANCES.

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
90	Ignition drive driven bevel gear and bearing (R and L)	0. 0025		0. 0045	0. 0065
91	Ignition drive shaft and ignition advance unit assembly (R and L)	0. 001		0. 0025	0. 0045
92	Ignition drive shaft and magneto drive gear bearing (R and L)	0. 002		0. 004	0. 0065
93	Ignition drive shaft and magneto adapter bore (R and L)	0. 002		0. 004	0. 0065
94	Magneto drive driven gears and adapter bores (R and L)	0. 002		0. 005	0. 0067
95	Tachometer drive idler gear and adapter bore	0. 002		0. 004	0. 006
96	Tachometer drive driven gear and adapter bore	0. 0015		0. 0035	0. 0055

b. INTERFERENCES.

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
97	Magneto drive gear and magneto drive gear bearing	0. 0015		0. 0035	

131. Main-Bearing Bores, Caps, and Bearings (par. 60)

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
98	Bore diameter of crankcase	3. 8140		3. 8145	
99	Inside diameter of main bearings when installed at proper torque tightness	3. 5045	3. 5050	3. 5055	
100	Main bearing thickness (std)	0. 1555		0. 1560	0. 1545
101	Clearance—main bearing and crankshaft	0. 0025	0. 004	0. 0045	0. 007

132. Oil Pressure Control Valve (par. 74)

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
102	Clearance—plunger in valve housing	0. 0005		0. 002	0. 004
103	Clearance—valve stem in valve housing	0. 003		0. 0085	0. 012
104	Regulator spring: 2.91-in free length (aprx) 2.00-in maximum solid height Scale reading: 107 ± 5 lb at 2.25-in length.				
105	Main oil pressure If main oil pressure is low, it may be increased by adding up to three washers CO–502708, under the housing cap.	60 psi		70 psi	

133. Oil Filter and Oil Cooler By-Pass Valves (par. 75)

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
106	Clearance—valve stem in housing (both valves).	0. 003	-------	0. 0085	0. 012
107	Spring data (both valves). 2.16-in free length (approx) 1.06-in maximum solid height Scale reading: 27.7±2.5 lb at 1.38-in length				

134. Oil Pump (par. 58)

a. DATA.

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
	Output of pump: 35 gpm at 2,800 rpm at 70 psi using SAE 50 oil at 180° F.:				
108	Depth of bore of upper (scavenge) pump.	1. 628	-------	1. 630	See ref. No. 111.
109	Depth of bore of lower (pressure) pump.	1. 503	-------	1. 505	See ref. No. 112.
110	Oil pump separator plate thickness.	0. 620	-------	0. 630	See ref. Nos. 111 and 112.
	End play between impellers and housing with pump bolted tight:				
111	Scavenge	0. 002	-------	0. 005	0. 008
112	Pressure	0. 002	-------	0. 005	0. 008

b. CLEARANCES.

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
	Pump drive shaft and housing bores:				
113	Scavenge housing	0. 0013		0. 0027	0. 005
114	Separator plate	0. 0013		0. 0027	0. 005
115	Pressure housing	0. 0014		0. 003	0. 005
116	Pump idler shaft and housing bores	0. 0000		0. 0014	0. 003
	Pump impellers and housing:				
117	Scavenge (radial clearance)	0. 002		0. 0027	0. 005
118	Pressure (radial clearance)	0. 002		0. 0027	0. 005
	Pump idler shaft and driven impellers:				
119	Scavenge	0. 0022		0. 0031	0. 0045
120	Pressure	0. 0022		0. 0031	0. 0045
121	Oil pump driven bevel gear and scavenge housing bore.	0. 0025		0. 0045	0. 006

135. Pistons (par. 72)

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
	Diameter of piston:				
122	Top of skirt — 90° to piston pin	5. 727		5. 729	5. 724
123	Bottom of skirt — 90° to piston pin	5. 732		5. 733	5. 729
	Width of ring groove:				
124	Groove No. 1 — top	0. 098		0. 099	0. 104
125	Groove No. 2	0. 098		0. 099	0. 103
126	Groove No. 3	0. 189		0. 190	0. 192
127	Groove No. 4	0. 188		0. 189	0. 191
128	Piston pin, diameter	1. 3750		1. 3752	See ref. No. 130
129	Piston pin bore, diameter	1. 3755		1. 3757	See ref. No. 130
130	Clearance, piston pin and piston	0. 0003		0. 0007	0. 0012

136. Piston Rings (par. 72)

a. Gap Clearance When Fitted in 5.750-Inch Ring Gage.

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
131	Top ring	0. 050		0. 060	0. 065
132	Second ring	0. 050		0. 060	0. 065
133	Third ring	0. 035		0. 045	0. 060
134	Fourth ring	0. 035		0. 045	0. 060

b. Clearance of Ring in Groove of Piston.

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
135	Groove No. 1—top	0. 0045	0. 0055	0. 0065	0. 0100
136	Groove No. 2	0. 0045	0. 0055	0. 0065	0. 0090
137	Groove No. 3	0. 0025	0. 003	0. 004	0. 005
138	Groove No. 4	0. 0015	0. 002	0. 003	0. 004

137. Starter Gear Grain (par. 46)

a. Clearances.

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
139	Starter idler gear shaft and accessory case	0. 0002		0. 0018	0. 0025
140	Starter idler gear bearing and shaft	0. 0025		0. 0041	0. 006
141	Starter gear hub and accessory case bearing	0. 004		0. 006	0. 008

b. INTERFERENCES.

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
142	Starter idler gear and bearing	0. 0015		0. 0035	

138. Valves (par. 55)

a. INTAKE VALVE.

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
143	Stem diameter	0. 497		0. 498	See ref. No. 144
144	Clearance—stem and guide	0. 0015		0. 0030	0. 005
145	Angle of seat with stem		45°15′	45°15′	

b. EXHAUST VALVE.

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
146	Stem diameter	0. 557		0. 558	See ref. No. 147
147	Clearance—stem and guide	0. 0035		0. 0050	0. 008
148	Angle of seat with stem		45°15′	45°15′	

139. Valve Guides (par. 55)

a. Intake Valve Guide.

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
149	Inside diameter	0. 4995		0. 5000	0. 502
150	Interference of guide and bore in cylinder head	0. 0010	0. 0015	0. 0025	

b. Exhaust Valve Guide.

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
151	Inside diameter	0. 5615		0. 5620	0. 566
152	Interference of guide and bore in cylinder head	0. 0020		0. 0035	

140. Valve Rocker (par. 79)

a. Interferences.

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
153	Valve rocker bearing and valve rocker	0. 0025		0. 0045	
154	Valve rocker roller hub pin and valve rocker (end of roller hub pin over in valve rocker)	0. 001		0. 001	
155	Interference of valve rocker roller hub pine and valve rocker roller hub (roller hub also locked to pin)	0. 0005		0. 0015	

b. Clearances.

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
156	Valve rocker roller and hub	0. 004		0. 005	0. 007
157	Side clearance of roller in valve rocker	0. 0035		0. 0075	0. 010
158	Valve rocker shaft and valve rocker bearing	0. 001		0. 0025	0. 005

141. Valve Seat Inserts (par. 55)

a. Intake Valve Insert.

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
159	Small diameter	0. 004	0. 005	0. 007	
160	Large diameter	0. 003	0. 000	0. 001	
161	Widtn of valve seat	0. 06		0. 09	0. 16
162	Angle of seat		45°		(see
163	Angle of relief (for narrowing width of seat)		30° and 60°		(text)

b. Exhaust Valve Insert.

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
164	Small diameter	0. 004	0. 005	0. 007	
165	Large diameter	0. 003	0. 000	0. 001	
166	Width of valve seat	0. 06		0. 09	0. 16
167	Angle of seat		45°		(see
168	Angle of relief (for narrowing width of seat)		30° and 60°		text)

142. Valve Springs (par. 55)

Note. Any spring that fails to register within 10 percent of manufacturer's recommendation at a given dimension will be rejected.

[All dimensions in inches unless otherwise noted]

Ref. No.	Point of measurement	Sizes and fits of new parts			Wear limits
		Min.	Desired	Max.	
169	Large—outer:				
	Scale reading: 124.4 lb±10% at 1.56 in				
	Scale reading: 85.0 lb±5% at 2.12 in				
170	Medium—intermediate:				
	Scale reading: 74.9 lb±10% at 1.56 in				
	Scale reading: 51.2 lbs±5% at 2.12 in				
171	Small—inner:				
	Scale reading: 40 lb±10% at 1.38 in				
	Scale reading: 25.8 lb±5% at 1.93 in				

143. Torque Specifications

	Min.	Desired (in.-lb.)	Max.
Main bearing studs in crankcase	-----	700	-----
Main bearing cap nut:			
Initial	-----	650	-----
Intermediate	-----	800	-----
Final	1, 200	1, 250	1, 300
Crankcase cross bolts	800	825	850
Connecting rod bolt	750	800	850
Cylinder base nuts	325	350	350
Damper hub screws (accessory end)	950	1, 000	1, 050
Flywheel mounting screws	950	1, 000	1, 050
Spark plugs	200	225	225
Transmission adapter mounting nuts	400	425	450
Valve rocker support nuts	175	175	200

APPENDIX
REFERENCES

1. Publication Indexes

The following publication indexes and lists of current issue should be consulted frequently for latest changes or revisions of references given in this appendix and for new publications relating to matériel covered in this manual:

Index of Administrative Publications	SR 310–20–5
Index of Army Motion Pictures and Film Strips	SR 110–1–1
Index of Army Training Publications	SR 310–20–3
Index of Blank Forms and Army Personnel Classification Tests.	SR 310–20–6
Index of Technical Manuals, Technical Regulations, Technical Bulletins, Supply Bulletins, Lubrication Orders, Modification Work Orders, Tables of Organization and Equipment, Reduction Tables, Tables of Allowances, Tables of Organization, Tables of Equipment, and Tables of Basic Allowances.	SR 310–20–4
Introduction and Index (Supply Catalogs)	ORD 1
Military Training Aids	FM 21–8
Ordnance Major Items and Combinations and Pertinent Publications.	SB 9–1

2. Supply Catalogs

The following Department of the Army Supply Catalogs pertain to the matériel covered in this manual:

a. Maintenance and Repair.

Antifriction Bearings and Related Items	ORD 5 SNL H–12
Cleaners, Preservatives, Lubricants, Recoil Fluids, Special Oils, and Related Maintenance Materials.	ORD 3 SNL K 1
General Tools and Supplies for Ordnance Base Armored Vehicle Maintenance Company.	ORD 10 SNL N–317
Items of Soldering, Metallizing, Brazing and Welding Materials; Gases and Related Items.	ORD 3 SNL K–2
Lubricating Equipment, Accessories and Related Dispensers.	ORD (*) SNL K–3
Major Items of Automotive and Semi-Automotive Vehicles (Including bicycles).	ORD 3 SNL G–1
Miscellaneous Hardware	ORD 5 SNL H–2

*See ORD 1, Introduction and Index, for published catalogs of the ordnance section of the Department of the Army Supply Catalog.

Oil Seals	ORD 3 SNL H–13
Ordnance Maintenance Sets	ORD 6 SNL N–21
Standard Hardware	ORD 5 SNL H–1
Tools and Supplies for Ordnance Base Automotive Maintenance Battalion.	ORD 10 SNL N–325
Tools and Supplies for Ordnance Heavy Maintenance Company, Field Army.	ORD 10 SNL N–9
Tools and Supplies for Ordnance Heavy Maintenance Company, Tank.	ORD 10 SNL N–37
Tools and Supplies for Ordnance Light Maintenance Company.	ORD 10 SNL N–8
Tools and Supplies for Ordnance Maintenance Battalion, Armored Division.	ORD 10 SNL N–65
Tools and Supplies for Ordnance Medium Maintenance Company.	ORD 10 SNL N–7
Tool-Sets (Common), Specialists' and Organizational	ORD 6 SNL G–27, Section 2
Tool-Sets (Special), Motor Vehicles	ORD 6 SNL G–27, Section 1

b. VEHICLE.

Tank, Medium, M46	ORD (*) SNL G–244

3. Explanatory Publications

The following explanatory publications contain information pertinent to this matériel and associated equipment:

a. CAMOUFLAGE.

Camouflage	TM 5–267
Camouflage, Basic Principles	FM 5–20
Camouflage Materials and Manufacturing Techniques	FM 5–20H
Camouflage of Rear Areas and Fixed Fortifications	FM 5–20G
Camouflage of Vehicles	FM 5–20B

b. DECONTAMINATION.

Decontamination	TM 3–220
Decontamination of Armed Force Vehicles	FM 17–59
Decontamination Procedures	SB 5–52
Defense Against Chemical Attack	FM 21–40
Miscellaneous Gas Protective Equipment	TM 3–290
Military Chemistry and Chemical Agents	TM 3–215

c. GENERAL.

Cleaning, Preserving, Sealing and Related Materials Issued for Ordnance Matériel	TM 9–850
Cooling Systems: Vehicles and Powered Ground Equipment	TM 9–2858
Dictionary of United States Army Terms	TM 20–205
Distribution and Issue of Ordnance General Supplies	SB 9–3
Explosives and Demolitions	FM 5–25
General Safety Manual	TM 20–350
Hand, Measuring, and Power Tools	TM 10–590
Inspection of Ordnance Matériel	TM 9–1100
Lubrication	TM 9–2835

*See ORD 1, Introduction and Index, for published catalogs of the ordnance section of the Department of the Army Supply Catalog.

Maintenance and Care of Hand Tools	TM 9–867
Military Vehicles	TM 9–2800
Motor Transport	FM 25–10
Ordnance Service in the Field	FM 9–5
Painting Instructions for Field Use	TM 9–2851
Precautions in Handling Gasoline	AR 850–20
Preventive Maintenance of Electric Motors and Generators	TM 55–405
Principles of Automotive Vehicles	TM 9–2700
Shop Work	TM 11–453

d. Maintenance and Repair.

Basic Maintenance Manual	TM 38–650
Instruction Guide: Care and Maintenance of Ball and Roller Bearings	TM 37–265
Ordnance Field Maintenance	FM 9–10
Ordnance Maintenance: Carburetors (Stromberg)	TM 9–1826B
Ordnance Maintenance: Electrical Equipment (Eclipse-Pioneer)	TM 9–1825C
Ordnance Maintenance: Electrical Equipment (Bendix-Scintilla)	TM 9–1825E
Ordnance Maintenance: Fuel Pumps	TM 9–1828A
Ordnance Maintenance: Vehicular Maintenance Equipment: Grinding, Boring, Valve, Reseating Machines and Lathes	TM 9–1834A

e. Operation.

Medium Tank M46	TM 9–718

f. Shipment and Standby or Long Term Storage.

Instruction Guide; Ordnance Packaging and Shipping (Posts, Camps, and Stations)	TM 9–2854
Ordnance Storage and Shipment Chart—Group G	TB 9–OSSC–G
Preparation of Unboxed Ordnance Matériel for Shipment	SB 9–4
Protection of Ordnance Matériel in Open Storage	SB 9–47

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